

08-29-2017

FILED

2017 SEP -5 PM 2: 03

REGIONAL HEARING CLERK
EPA REGION VI

Reference Docket Numbers:

SDWA-06-2017-1110

SDWA-06-2017-1112

SDWA-06-2017-1111

To Whom It May Concern:

I am writing you this letter to tell you how the Salt Spill has affected my land and me. For many months my land was reading off the charts (too high to measure) salt content in the water areas of my land. Everyone that has been involved in the salt spill has stated that they have no idea of the long term effects. It could not be used for any animal to drink from the creek involved and may continue to be a problem. There are many wells on that area of my property. It took everyone months to figure out the cause of the salt spill. I still have no idea and no one else knows how the salt spill will affect my land in the future. I feel that my land has been forever damaged and I am worried about the long term effects of it.

Sincerely Yours,



Andrea Gleba

7738 W. Mescal Street

Peoria, AZ. 85345

(623)-234-2274—Home

(623)-418-5948--Cell

October 11, 2017

Hearing on Proposed Orders

SDWA 06-2017-1110, SDWA 06-2017-1111 and SDWA-06-2017-1112

Tulsa County Courthouse

Room 119

500 South Denver, Avenue

Tulsa, Oklahoma 74103-3844

9:15 – 10:45: Jireh Resources, LLC

10:45 – 12:15: Warren American Oil Company, LLC

12:15 – 1:15: Lunch

1:15 – 2:45: Novy Oil and Gas, Inc.

2:45 – 3:45: Public comments

FILED
2017 SEP -5 3:03
REGIONAL HEARING CLERK
EPA REGION 6

1002 Star Street
Claremore, OK 74017
August 29, 2017
1-(580)-716-6815

Ms. Lorena Vaughn
Regional Hearing Clerk (6RC-D)
U.S. Environmental Protection Agency
Region 6
1445 Ross Avenue, Suite 1200
Dallas, Texas 75202-2733

The submitted written comments are in reference to the following three Document Numbers:

SDWA-06-2017-1110 (Jireh Resources, LLC)

SDWA-06-2017-1112 (Novy Oil and Gas, Inc.(Grayhorse Operating LLC)

SDWA-06-2017-1111 (Warren American Company, LLC)

I appreciate the EPA's efforts in determining the saltwater leakage into the North Bird Creek water in Osage County, Oklahoma. I also support the EPA's pursuit of corrective actions against those Corporations or Limited Liability Companies whose saltwater injection wells were determined to be responsible for that leakage. It would appear that examinations and testing by the EPA investigative team determined that the named companies or LLC's failed to confine injected fluids to the approved or authorized injection zone.

I support the EPA's Administrative Orders requiring the Jireh Resources, LLC, the Novy Oil and Gas, Inc. (Grayhorse Operating LLC), and Warren American Company, LLC to either "shut-in" injection wells as listed or to "shut down" injected wells as listed for the various companies. While those companies will be impacted by those actions, landowners and pasture grazing operators have already been financially impacted, AND may continue to be adversely affected if the proposed EPA actions are not implemented.

The examination of the cause of the saltwater leak took over a year to determine that the salt water surfaced from salt water injection wells. The loss of a year (August of 2016 to August of 2017) of livestock grazing on the Osage bluestem grass resulted in a financial losses to land owners and livestock operators..

There may be other abandoned salt water disposal wells or improperly capped oil wells that will emerge. There is reason to believe that there will be future problems with the older oil fields. I would hope that there would be continued monitoring and oversight of all saltwater disposal wells as well as review of surface saltwater or oil spills. **How this particular saltwater "spill" is managed will set precedent for future spills.** The investigation of such spills needs to

Surber - EPA letter of 8-29-2017 (continued)

Page 2

have independent, trained, and available personnel to collect the needed information to be submitted to certified testing laboratories. There needs to be an immediate response to the emergency. This can only properly done by the EPA. The EPA has the regulations and authority,

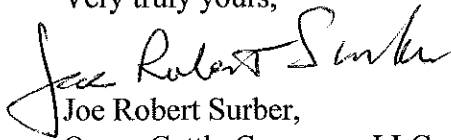
The Osage Cattle Company, LLC, of which I am the manager and sole proprietor, leases the one hundred and fifty (155) acres from a non-restricted Osage native, Mr. Lawrence Potts. I have leased this property for the past ten (10) years and my brother years before 2007. The land remains unusable since August 2016 since the only source of water is the unusable North Bird Creek.

Legal Description of above grazing lease property:

SW/4 of the NW/4, NW/4 of the SW/4
Section 18 of T27N R8E
N/2 of the SE/4 Section 13 T27 N R7E

I am appreciative of the efforts of the EPA to initiate action to limit the damages resulting from the saltwater injection wells contamination of the North Bird Creek water source. Thanks for your assistance in this situation.

Very truly yours,



Joe Robert Surber,
Osage Cattle Company, LLC



The Nature Conservancy
Oklahoma Chapter
10425 S. 82nd E. Avenue
Suite 104
Tulsa, OK 74133

September 1, 2017

Ms. Lorena Vaughn
Regional Hearing Clerk (6RC-D)
U.S. Environmental Protection Agency
Region 6
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

via email and first class mail

Re: SDWA-06-2017-1110 (Jireh Resources, LLC)
SDWA-06-2017-1111 (Warren American Company, LLC)
SDWA-06-2017-1112 (Novy Oil and Gas, Inc. (Grayhorse Operating, LLC))

Dear Ms. Vaughn:

Thank you for the opportunity to submit comments regarding the U.S. Environmental Protection Agency's above referenced proposed Administrative Orders. The Nature Conservancy is very supportive of these EPA efforts to address the serious water quality problems that have become apparent in Bird Creek over the past year. The Nature Conservancy's 40,000-acre Tallgrass Prairie Preserve is located about one mile to the east from the impacted stretch of Bird Creek.

Osage County is an important place to The Nature Conservancy. Over the past 28 years, we have established and managed a fully functional tallgrass prairie ecosystem at our Tallgrass Prairie Preserve. We are fortunate to be in a community which supports the conservation of the tallgrass prairie and its ecosystem, and to work alongside so many landowners in Osage County with like-minded goals. The Conservancy shares the community's concerns regarding the need to ensure high water quality for the benefit of people, our economy, and nature.

As a landowner and member of the Osage County community, the Conservancy recognizes the importance of the mineral estate to the Osage Nation. The Conservancy has always worked collaboratively with the lease holders and Bureau of Indian Affairs to minimize environmental impacts of the oil and gas activity. By working together, we have been able to reduce some of the impacts of the more than 200 operating wells that are on our preserve.

From what we can gather from past press stories on the Bird Creek situation, the water quality impacts may be related to deteriorating or substandard equipment and infrastructure in

saltwater disposal wells in area oil fields. If that is the case, we encourage you to also assess the status of the oil field infrastructure on the Tallgrass Prairie Preserve that is adjacent to the Bird Creek impacted area, some of which is over 100 years old. The legal location of the oil field leases on Conservancy property are: SW/4 of Section 17 and the SE/4 of Section 18, all in Township 27 North, Range 8 East, Osage County, OK.

Thank you for considering these comments. If you have any questions or would like any additional information, please feel free to contact me at 918-585-1117 or at mfuhr@tnc.org.

Sincerely,



Michael Fuhr
Oklahoma State Director

Osage Land & Cattle Co.
2431 NOWATA PLACE
BARTLESVILLE, OKLAHOMA 74003
(918) 338-2332

FILED
2017 SEP -5 PM 2:01
REGIONAL HEARING CLERK
EPA REGION VI

September 1, 2017

Ms. Lorena Vaughn, Regional Hearing Clerk (GRC-D)
U.S. Environmental Protection Agency, Region 6
1445 Ross Avenue, Suite 1200
Dallas, Texas 75202-2733

Re: Comment Letter on Administrative Orders: **SDWA-06-2017-1110** (Jireh Resources, LLC); **SDWA-06-2017-1112** (Novy Oil and Gas, Inc. (Grayhorse Operating, LLC)); and **SDWA-06-2017-1111** (Warren American Company, LLC)

Dear Ms. Vaughn:

Osage Land & Cattle Co., together with BEPCO, L.P. are submitting the following comments in response to recently posted Administrative Orders to Jireh Resources, Novy Oil and Gas, Inc. – Grayhorse Operating, LLC, and Warren American Company, LLC related to oil and gas operations on the Chapman Ranch in Osage County, Oklahoma. Chapman Ranch is owned and operated by Osage Land & Cattle Co. BEPCO, L.P. and Osage Land & Cattle Co. are part of the Bass Enterprises Companies.

We support the proposed administrative controls based on observations and comments provided below:

- **Timeline of Key Events**

- Summary of Events Key to Understanding of Concerns

- Week of Aug 7, 2016 – A stagnant black sheen and aquatic life kill was noticed on Bird Creek at bridge crossing by ranch employees. Sludge-like film observed on shoreline sediment and the plant life had been adversely affected. Notifications made to BIA and USEPA.



- August 16, 2016 – USEPA made initial visit to site. A field reading of >80,000 ppm chloride was noted at the bridge and visible and olfactory indications of brine and oil were noted. Using a meter provided by BIA, ranch personnel continued downstream to conduct a comprehensive assessment of impact to Bird Creek. Initial survey noted a chloride impact extending 4.5 miles downstream from bridge. A second point of chloride readings similar to the bridge was noted where the creek intersects a tributary, about 0.5 miles downstream of bridge (hereinafter referred to a creek intersection). Chloride level was observed at 65,000 ppm. At the conclusion of visit, USEPA called for continued monitoring as their primary response.
- August 30-31, 2016 – Ranch management met with representatives from Jireh Resources, LLC, Warren American, Grayhorse Operating, BIA, and USEPA. The group was briefed on failed integrity at Jireh 18W and a recent failed mechanical integrity test (MIT) at an unnamed Warren well. Visit to area by ranch management indicated a workover rig and fresh cement job at the Jireh 18W injection well and disconnected injection line and rack of new tubing on the Warren American B-9 location.

The theory of a dumping or surface spill event as potential source was discussed in detail and based on current practices by the operators of using local on-site injection/disposal wells, access to the bridge through ranch resident entrance and lack of turn around or easy egress, operators were quick to agree that a dumping event was illogical.

A key take-away from initial meeting was that neither USEPA nor BIA was claiming jurisdiction or authority over corrective actions, despite our belief that the watercourse should be protected under the Clean Water Act. EPA mentioned that continued monitoring and inspection would take place. BIA stance was “if anything comes up, let us know.” There was no direction of any options to aggressively remediate the sheen or excessive chloride levels.

August Rainfall: 0.82 inches

- Week of September 15, 2016: USEPA attempts an electromagnetic survey of a small local area near bridge. Several instrumentation problems. Study was deemed inconclusive. No report of findings/conclusions was made available.
- September 27, 2016: Ranch owner management requests more aggressive action and direction from EPA under the Clean Water Act as stream continues to show impact.

September Rainfall: 3.12 inches

- October 3, 2016: Ranch owner management requests of EPA that the area pools near the bridge be pumped out through a cooperative agreement with the operators. Information was also received from Oklahoma DEQ that the City of Pawhuska sees the creek issue a potential threat to the city’s water supply.
- Week of October 3, 2016: 3.2 inch rain event noted on October 4. Creek was flowing over the bridge. Review by an OK DEQ representative on October 5

indicated that “water had previously ran over road at the bridge adjacent to the brine pool. The two foot culverts under the bridge were still shooting full bore and churning that pool and the whole creek downstream was rolling full. As far as flushing out the creek and getting the existing salt out of there, it was about the best case scenario you could hope for.”

During this period, samples were also collected from creek and nearby injection wells by EPA for comparison. Results obtained from the FOIA request indicated that a comparison of major cations/anions indicated a strong correlation to Mississippian Chat injection fluids.

- October 16, 2016: EPA returned to site and took field measurements; levels at the bridge were noted at 52,000ppm chloride. A reading of 45,000 ppm chloride was noted at creek intersection.
- October 27, 2016: EPA recorded 70,000 ppm and water temperatures of 100 degrees at bottom of creek at the bridge location. EPA indicated that samples collected earlier in month showed a positive correlation between the Jireh and Warren injection wells and the water in the creek.
- October 28, 2016: Ranch owner management again appeals to EPA for more aggressive action and direction under the Clean Water Act due to continued impact.

October Rainfall: 6.05 inches

November Rainfall: 0.38 inches

- December 7, 2016: BIA takes reading at bridge of Bird Creek: 49,900 ppm chloride recorded. A reading of 47,000 ppm chloride was noted at creek intersection.

December Rainfall: 0.82 inches

January 2017 Rainfall: 3.22 inches

February Rainfall: 0.96 inches

March Rainfall: 2.86 inches

- April 24, 2017: USEPA indicates that formal information requests were submitted related to underground injection control operations of the operators in the area. Also letters were submitted requesting participation in a dye test of injection wells. Data indicates that this study never took place.

April Rainfall: 12.90 inches

- May 4, 2017: Meeting with US EPA Region 6 Administration staff at bridge site – plan of assessment was outlined. Substantial rain event noted on May 3rd that was over the bridge on May 3, but receded to flowing through culverts on May 4. BIA Readings: 23,000 ppm at bridge and 41,600 ppm at creek intersection.
- Week of May 15, 2017: Grayhorse Operating shuts in Osage 15 SWD and moves in workover rig.
- May 23, 2017: EPA conducts a detailed survey of the creek and begins process of installing continuous monitor probes in Bird Creek. Readings in creek: 3300 ppm at bridge (Station 2), 46,600 ppm at creek intersection (Station 6). Two additional points in creek identified with elevated chloride levels (Stations 4 and 5).

- May 25, 2017: Went to Osage 15 SWD site while workover crew was on-site and talked with Grayhorse Operating, LLC. Operator mentioned that they knew of potential integrity problem with well in August 2016.
May Rainfall: 5.36 inches
- June 28, 2017: Field reading at Creek intersection area: 51,000 ppm, 95 deg F.
June Rainfall: 2.81 inches
- Based on the above information, the ranch management made the following observations:
 - Several cases of failed integrity within various area injection/disposal wells were noted;
 - After large rainfall events capable of significant flushing of creek, chloride levels dropped but then returned. Almost 40 inches of rainfall in less than 1 year and significant chloride levels still persist within creek.
 - Chloride levels at the bridge began slow decline with workover rehabilitation or shut-in at Jireh and Warren injection wells and then experienced a rapid decline after shut-in of Grayhorse #15 SWD.
 - Field observations during May 2017 detailed survey conducted by USEPA indicated that the chloride "hot spots" were located within the stream bed but seemed consistent throughout rain events. There was no correlation to depth of water and the presence of a chloride "hot-spot".
- **Impact or threat to Ranch Property**

Grazing

The area of Bird Creek impacted by the contamination is located in high-quality livestock grazing pastures. Based on recent field measurements made available to the landowner, approximately 3500 acres of pasture land has been off limits to cattle for the purpose of grazing due to the contamination for over a year. Currently, Total Dissolved Solids measurements in localized impacted areas of the creek have ranged from 2,342 ppm to over 44,000 ppm, which according to information received from the Oklahoma Cooperative Extension Service at Oklahoma State University, can adversely affect the overall health of livestock and should be avoided if over 5,000 ppm.

Ecological Habitat – Tall Grass Prairie / Threat to aquatic life

The Chapman Ranch and Bird Creek are situated in one of last remaining areas of a tallgrass prairie eco-system in the world and is adjacent to the protected Nature Conservancy Tallgrass Prairie Preserve. Originally spanning portions of 14 states from Texas to Minnesota, the original tallgrass prairie area has been dramatically reduced by conversion to cropland, leaving less than 4% of the original tallgrass prairie. The Chapman Ranch ownership and nearby ranch owners, like the Preserve, prides itself on maintaining this fully-functioning portion of the tallgrass prairie ecosystem and employs various conservation measures including prescribed burning and well-managed grazing.

The contamination to Bird Creek resulted in a wildlife kill of fish, turtles, crayfish, mollusks, and left at least a one-mile stretch of creek void of any aquatic life for several months. Historic poor management of oil & gas operations has plagued Osage County for years. Waters in Osage County that do not currently meet applicable water quality standards are listed in the 2012 List of Impaired Waters compiled by the state of Oklahoma under Section 303(d) of the Clean Water Act. A total of nineteen (19) Osage County lakes and streams are on the list of impaired waters. One source of impairment for six (6) of 19 impaired streams and lakes in Osage County is listed as Source ID number 102- "petroleum/natural gas activities (Legacy)".

Nearby domestic water wells

Chapman Ranch operations in the area include the use of two domestic water wells located approximately 1600 feet from the contaminated portions of Bird Creek. The wells provide potable water to two ranch homes that are occupied by Chapman Ranch personnel and their families. These wells are approximately 400 feet in depth and have been tested three times by ranch management since the initial discovery in August 2016. There have been minor fluctuations in key indicator cation elements that require continued monitoring since significant change to these cation ratios may indicate a change in groundwater quality. Acting on the side of caution, bottled water has been used for drinking water.

Bird Creek Watershed – City of Pawhuska

The Bird Creek Watershed encompasses an area of approximately 1,137 square miles and extends across 4 counties in Northeast Oklahoma including portions of Osage, Washington, Rogers and Tulsa Counties. The watershed contains fourteen (14) communities, including nearby Pawhuska and other communities within Osage County and extends as far south as Tulsa. The city of Pawhuska's primary and preferred water source intake is from Bird Creek located approximately 10 miles downstream of the Chapman Ranch. Pawhuska City Manager Mike McCartney said that city's water supply sources have not been affected but that "out of an abundance of caution" and the potential threat of a reoccurrence, a switch was made to have Pawhuska Lake, which is fed by Clear Creek, serve as the primary water source instead of a water supply linked to Bird Creek. This has been a significant expense to the City based on verbal discussions with the City.

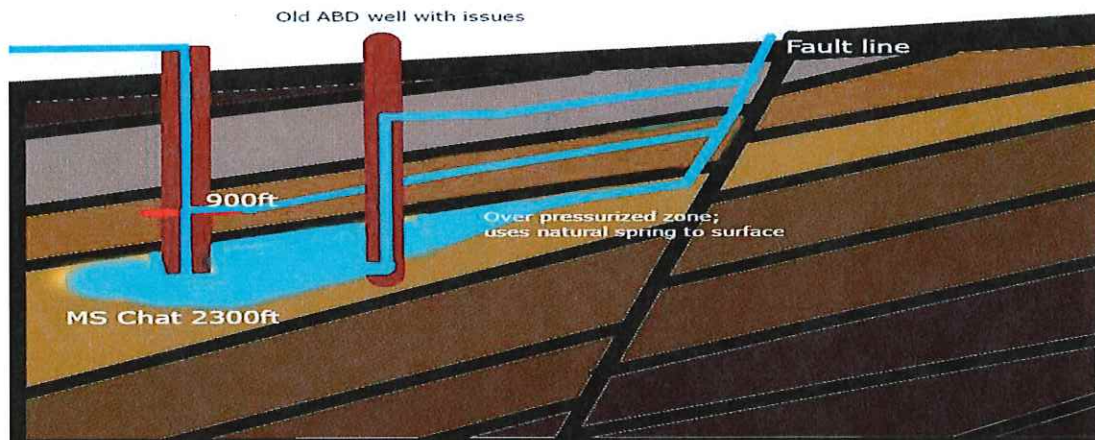
- **Abundance of Abandoned Wells in Area – Accountability**

Within the area of Chapman Ranch, there are dozens if not hundreds of abandoned wells visible within the pasture areas and an indeterminable number that may lie beneath the land surface. Abandoned wells are potential receptacles for household garbage, dead animals, worn out machinery, and liquid wastes. More importantly, unplugged or improperly plugged wells can act as conduits for the movement of oil, gas, salt water, or other substances into any groundwater strata through which the well may have been drilled, depending on how the well was constructed and its current condition. Through seepage, the substances may enter groundwater strata and adversely impact groundwater quality. Casing corrosion or the absence or

degradation of cement in the annular space around the well casing can also provide holes or openings for pollutant migration to reach groundwater aquifers or even reach the surface waters. In a review of available well data in the immediate vicinity of the Bird Creek /Chapman Ranch area (roughly 3-4 square miles), over 118 well locations were individually reviewed, many drilled prior to 1960 and most of them abandoned. Casing and cementing records were virtually unusable from the database to determine casing string depths or cementing of shallow formations. Photos are provided herein as examples of the numerous abandoned wells that are readily visible in the vicinity of Bird Creek.



Without effective and enforceable plugging program, the abandoned well can easily serve as a conduit for formation fluid migration upward (see sketch below). These fluids can migrate upward via the open abandoned casing or via annular conduits from corroded and poorly cemented casing strings and seep into fresh water aquifers or reach the surface. This is a very plausible explanation surrounding the contamination in Bird Creek and even more plausible with the fact that many wells in the area were drilled in the 1930's, 40's, and 50's. It was not until the mid-1960's, when states enacted regulations to protect fresh water that included proper cementing of casing strings.



It has been documented that the agencies regulating oil & gas development in Osage County have not historically been accountable for the disposition of abandoned wells. In an October 2014 report by the U.S. Department of Interior (USDI) Inspector General's Office, the regulatory agency's policies and procedures were noted as being incomplete, not dated, and not having final approval by the Superintendent. 25 CFR Part 226 gives the agency superintendent significant discretion in managing the Osage oil & gas programs. Specifically, it states the "lessee shall not shut down, abandon, or otherwise discontinue the operation or use of any well for any purpose without written approval of the superintendent." This example of wording in regulations encourages inconsistent practices by operators, including not properly plugging and leaving wells unsecured and susceptible to corrosion. It should be noted that responsible operators have typically addressed these risks. The USDI further noted that "historically the Council has not plugged wells so that the wells can potentially be operated later as technology advances the ability to recover additional oil and gas."

- **Geology, Permitting and Monitoring Considerations**

Over the past year of involvement in the assessment of the contamination at Bird Creek on the Chapman Ranch, several concerns have been raised around insufficient consideration of geologic formation characteristics within the Mississippian Chat and around the permitting and monitoring practices of injection/salt water disposal wells in the Bird Creek Area. For example, the 2014 USDI report cited minimal analysis is common for review of applications for permits to drill (APD) and there was no adherence to specific standards for drilling or workover approvals, even for injection wells. Without a regulatory interest in formation characteristics such as hydraulic fracture initiation pressure, there is no way to evaluate the safe limitations on injection pressure that would prevent a loss of zone isolation. Loss of vertical zone isolation could threaten shallower formations, including fresh water sources. Further, if a hydraulic fracture were allowed to be created, not only would vertical zone isolation be threatened, but lateral growth of such an induced fracture could transport high pressure injectants (produced water in this case) miles away from the point of injection, perhaps to intersect with natural pathways to groundwater or even the surface that, without the motive force of the injection system, would have been benign. Poor operating practices coupled with a lax regulatory framework, especially in areas of very marginal oil and gas resources, can (and has) led to key factors possible being overlooked. This is a recipe for poor outcomes like we see in this instance at Bird Creek.

Mississippian Chat Reservoir Unit - Geologic Considerations

In review of the basic geology of the Mississippian Chat reservoir, key factors were noted that question the suitability of the Chat reservoir for re-injection of formation fluids or water-flooding production practices. One key principle of disposal wells or injection wells is the disposal/injection interval must be sealed above and below by unbroken, impermeable rock layers and, to be effective, must be homogenous enough to provide a degree of lateral continuity that would safely accommodate such injection volumes. Geologic publications

indicate that the Chat interval exhibits lateral and vertical variations in reservoir properties because of its deposition. Locally, production is driven by matrix properties (porosity and permeability not enhanced by natural fractures) in some areas; whereas, in other areas, natural fractures play a dominant role. On a larger scale, the lack of homogeneity could lead to compartmentalization into small blocks that would be poorly suited to large-scale water disposal.

Available reports on the Mississippian Chat reservoir indicate that the unit is situated at an erosional unconformity between the Pennsylvanian and Mississippian system and is unique because it exists as a weathered or detrital interval of tripolitic or more dense chert at the top of Mississippian sequence. The term "tripolitic" is significant because it refers to a chert that has been highly weathered by meteoric waters (common along unconformities) and which is light-weight because of porosity formed during subareal exposure (i.e., weathering). It is often described as a "soft, weathered chert". Because of its deposition, this unit is susceptible to and frequently associated with fracturing (both natural and induced by injection). Again, it stands to reason that a highly variable, soft and weathered rock sequence that is commonly fractured provides challenges to maintaining vertical formation containment and lateral injection accommodation. To make matters worse, the Kansas Geologic Survey noted that operators often experience adverse permeability behavior during secondary recovery (i.e., injection) in the Mississippian Chat reservoir. This is a situation where natural formation properties make it difficult to inject water into the pore structure of the same zone that is producing oil and gas. In a waterflood project, where water injection into oil producing formations to enhance oil recovery is essential, this challenge can be "overcome" by injecting produced water at a pressure high enough to fracture the rock (higher than frac pressure). This act threatens the vertical containment of the zone and invites growth of the induced fracture in ways unknown and unknowable to the operator.

Formation fluid temperature of the Chat reservoir is a function of depth and the geothermal gradient in a geographic region. In Oklahoma and Kansas, the typical geothermal gradient is 1.5 degrees F / 100 feet of depth). At surface temperature of 75 degrees F, the formation temperature is 112.5 degrees F. This correlates with the observed temperatures recorded in the creek near the bridge.

Reservoir Engineering – Allowable Injection Pressure

A preliminary review of the injection pressures used in the MS Chat injection wells indicates the possibility of down-hole injection pressures exerted on the MS Chat reservoir unit may actually induce fracturing within the unit. This would provide a mechanism by which a formation fluids can disperse out into a network of intersecting fractures or faults that could eventually reach a nearby abandoned well, a nearby well experiencing mechanical integrity issues, or even the ground surface.

Two parameters are needed when assessing the potential effect of down-hole pressures on the Chat reservoir unit:

1. The frac gradient of the Chat reservoir unit; and
2. The calculated bottom hole pressure exerted on the formation.

The frac gradient, expressed in psi/foot, is the pressure required to induce fractures in rock at a given depth. There is no readily ascertainable published information concerning the specific measured frac gradient of the Mississippian Chat reservoir unit in Osage County. However, based on input from multiple petroleum reservoir engineers, an average frac gradient for a reservoir rock generally ranges from 0.5 psi/ft to 1.0 psi/ft. The lower range would represent rock that is weak, soft, or susceptible to fracturing whereas the upper end would represent rock that is hard, dense, and has a well cemented matrix. Based on discussions with geologists and engineers experienced in the Osage County area, the frac gradient within the MS Chat reservoir would likely be in the lower range near 0.5 psi/foot citing conditions similar to those discussed above in the geologic factors section. Given the average depth of the Chat producing interval in the Chapman Ranch area of 2,500 feet, the frac pressure would be approximately 1,250 psi. It is of interest that the frac gradient can be calculated using methods such as a Step-Rate Test but no such data is available for these comments.

The bottom-hole injection pressure exerted on any formation, expressed in (psi), is expressed as:

- o pressure exerted at the surface (SP) + hydrostatic pressure of fluid column in pipe (HP) – friction pressure from the movement of fluids down the tubulars; or
BHP = SP+H-FP (equation 1)

Most injection wells in this area have been assigned limits of 200 psi surface injection pressure and a volume limit of 90,000 bbls/month. As a historical note, this is actually an increase from 100 psi allowable injection pressure and 45,000 bbls/month set previously.

Hydrostatic pressure is a function of the fluid density and total column height of fluid (produced water in this case). Assuming 2500 feet in depth and a Sg of produced water of 1.07 (8.96 ppg or 0.465 psi/ft), the calculated hydrostatic pressure would be 1162.5 psi.

Friction pressure (FP) becomes the last value to consider. This value is based on a number of parameters including pipe diameter, pipe roughness factor, pipe length, flow rate, fluid density and fluid viscosity. In most all cases, 2 7/8 inch tubing is used for the injection wells. Assuming a fluid density of 8.96 lbs/gal, a viscosity of 1 centipoise, and using the depth and diameter of the tubing, the friction loss is calculated at 49 psi.

Application of **equation (1)** would result in a maximum downhole pressure of **1313.5 psi**. See below:

$$\text{BHP} = \text{SP} + \text{HP} - \text{FP}$$

$$\text{BHP} = 200 \text{ psig} + 1162.5 \text{ psi} - 49 \text{ psi}$$

$$\text{BHP} = 1313.5 \text{ psi}$$

While many operators are assigned this 200 psi limit, there are no reliable rules to govern this. In fact, the federal underground injection control (UIC) rule for Osage Mineral Reserve (40 CFR 147.2900) provides specifications for the injection/ disposal wells in Osage County, including detailed operating requirements for these wells. Under 147.2912(b)(1), a calculation is provided whereby operators can determine the injection limitations. This equation is:

$$P_m = (0.75 - 0.433 S_g) d \quad (\text{equation 2})$$

where:

P_m = surface injection pressure at the wellhead in (psi)

S_g = specific gravity of injected fluid (unitless)

D = injection zone depth in feet

Application of **equation (2)** would result in a maximum surface pressure limit of **716.73 psi** and going back to **equation (1)** the bottom-hole injection pressure for the Chapman Ranch area would be as follows:

$$\text{BHP} = \text{SP} + \text{HP} - \text{FP}$$

$$\text{BHP} = 717 \text{ psig} + 1162.5 \text{ psi} - 49 \text{ psi}$$

$$\text{BHP} = 1830.5 \text{ psi}$$

RESULT: When we compare this to a frac pressure of 1250 psi calculated for the Chapman Ranch area above, the bottom hole pressure in both calculations exceeds the formation frac pressure and the fluid injected into the Chat reservoir unit is being injected at sufficient pressure to induce fractures. Again, these injection conditions exceed the formation's ability to maintain vertical containment and lateral accommodation within the zone. Note that even at **100 psi** surface pressure, the bottom-hole pressure may be aggressively close to formation frac pressure. Therefore, it is plausible (even likely) that the injection pressures allowed 40 CFR 147.2900 result in bottom-hole pressures that can induce fractures within the Chat reservoir.

Mechanical Integrity Testing

40 CFR 147.2900 and individual injection well permits provide the operator with mechanical integrity testing requirements. Per the permit, a mechanical integrity test (MIT) is required prior to initiating operations and every five years. However, 40 CFR 147.2900 provides options to demonstrate mechanical integrity, some of which include simple monitoring of gauges. There are even case-by-case programs approved by the Osage Superintendent. It should be noted that

most injection wells in the Chapman Ranch area are supposed to undergo a pressure test every five years which are reportedly monitored by EPA or Osage Council personnel.

Based on field observations during workover operations, concern was raised over the accuracy and verifiability of the MIT test results. First, a request of available records through the Freedom of Information Act (FOIA) was made to both the BIA and USEPA Region 6. No data was ever received from the BIA and the EPA data was limited. The only MIT data form was on the Jireh 18W well after the 2016 workover was completed. Any other MIT records were not provided with the EPA packet of FOIA information. The only records were on the Osage Tribe web page – Environmental Data Mapper. The MIT data was marginal, but none of the 7 injection/disposal wells identified in the referenced Administrative Orders had current MIT data available. The last passing MIT date was in 2011. Of the MIT records made available, all wells had prior histories of MIT failure. This raises concern over the data being readily accessible and verifiable for the purpose of establishing trends or even current status of any of these wells.

In addition, a concern was noted involving a sequence of events noted with the Grayhorse 15 SWD well. On May 25, 2017, the operator verbally noted to ranch management that the Grayhorse #15 SWD had mechanical integrity problems in August 2016, coincidental to the time that contamination was discovered in Bird Creek. An August 18, 2016 inspection by US EPA Region 6 indicated that the SWD was still pumping and that the gauges were not working properly and pressures could not be verified. Information from the USEPA Annual Disposal/injection Well Monitoring Report indicated that the Grayhorse 15 SWD continued to receive waste water at an average rate of 70,000 bbls/month as late as March 2017. In May 2017, a workover rig began pulling casing and tubing from the well. The tubulars were severely corroded and riddled with holes. Discussions with petroleum engineers indicated that pipe in that condition had likely been deteriorating for many years and would certainly not pass a MIT pressure test.



This raises concern over the accuracy and recommended testing interval of the MIT process under 40 CFR 147.2900. It further raises questions as to compliance with the individual UIC permit (No: 06S1261P5258) that states in Part II (E)(2) – if the well “fails to demonstrate mechanical integrity during a test, or a loss... becomes evident during operation, the operation shall be halted immediately and shall not be resumed until the Regional Administrator gives approval to recommence injection. “ Available information indicates potential issues arose in August 2016, but the well continued to operate for several months.

- **Final Comments**

Osage Land & Cattle, LLC and BEPCO, L.P. have been closely following the activity, monitoring, and assessment work that has been on-going since last year. We approve the administrative orders **SDWA-06-2017-1110** , **SDWA-06-2017-1111** and **SDWA-06-2017-1112** as an appropriate course of action because of evidence highlighted above that suggests contamination observed in Bird Creek is likely associated with injection into the Mississippian Chat reservoir and mechanical integrity failures in the injection and disposal wells in the area that has allowed for formation water to no longer be controlled due to the existence of abandoned wells, faults and fractures in the area that have reached the surface in the base of the creeks and various discrete points.

While we feel strongly toward approval of the Administrative Order, we also seek consideration from the US EPA to also apply additional administrative controls in the permitting, testing, and monitoring that addresses improved preventative requirements and establishes a management and enforcement process that can be verifiable and accountable for operations, including:

- Well construction
- SWD/injection permitting
- SWD/injection well monitoring & reporting
- P&A / orphan well program management

If you have any questions or desire additional information, please feel free to contact Bill Biehl at (817) 821-8016 or wbiehl@basspet.com or R.D. Farr at (918) 338-2332 or rdfarr@elcoyote.com .

Respectfully submitted:



Bill Biehl, PG
EH&S Manager
BEPCO, L.P (on behalf of Osage Land & Cattle Co.)

Ct: R.D. Farr, Osage Land & Cattle Co.

Ron P. Reed

P.O. Box 695

Pawhuska, Oklahoma 74056

FILED

2017 SEP -5 PM 2:00

REGIONAL HEARING CLERK
EPA REGION VI

August 28, 2017

Ms. Lorena Vaughn, Regional Hearing Clerk (6RC-D)

U.S. Environmental Protection Agency

Region 6

1445 Ross Avenue, Suite 1200

Dallas, Texas 75202-2733

RE: SDWA-06-2017-1110 (Jireh Resources, LLC)

SDWA-06-2017-1112 (Novy Oil and Gas, Inc. (Grayhorse Operating, LLC)

SDWA-06-2017-1111 (Warren American Company, LLC)

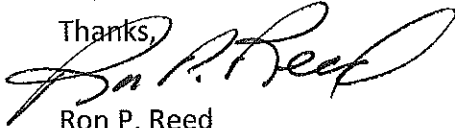
Comments on above described referenced docket numbers.

Our family has been in the ranching business for five generations in Osage County. North Bird Creek runs directly onto our leased grazing property. On August 16, 2016 I was fully stocked with cattle when I was notified of a saltwater problem; that the water tests had resulted in ranges over 80,000 TDS. I was first notified by the Superintendent of the BIA that the BIA inspectors had discovered the possibility that semi truck loads of salt water had been dumped into a pool of water on Bass Brothers Osage Ranch. This was proven completely false. I immediately removed all livestock from the leased property and have not restocked the property since that date; causing a significant financial burden. I now have lost revenue from three grazing seasons

As TDS levels increase, the threat of killing cattle and/or decreasing their weight gain is very concerning. While water temperature readings have been extreme, TDS levels have increased, and residual oil on surface of creek banks has been present; I approve the proposed order of the EPA to take the necessary steps with the injection wells in the area to eliminate the problem. The impact we would face if this problem was not eliminated would be detrimental to the environment and our ranching business. This problem has to be solved by all means necessary to protect the valuable resources and preserve the environment for generations to come.

I appreciate the actions of the EPA and support all efforts to identify and correct the problem. I think the regulatory monitoring of North Bird Creek is a step in the right direction to conduct the EPA's proposed order.

Thanks,

A handwritten signature in black ink, appearing to read "Ron P. Reed". The signature is fluid and cursive, with the first name "Ron" being particularly prominent.

Ron P. Reed

Reed Family Ranch, LLC

October 11, 2017

[illegible]

Proposed Hearing: SDWA 06-2017-1110, SDWA-06-2017-1111, and SDWA-06-2017-1112
October 11, 2017

Name	Phone number	Email address	Mailing Address
JOHN TUCKER	918 582 1173	JTUCKER@HENDEROKLA.COM	Box 21100 Tulsa OK 74121-1100
Brian Tubody	918 665 6543	bibtody@mcmanlaw.com	1430 S. Bullard Ave. Tulsa OK 74119
Doug Morton	918 269 5625	DMORTON@WATZELHUNT.COM	6585 S. YALE AVE TULSA, OK 74136 SUITE 800
Michael May	316-794-7200	MMAY@112201.COM	P.O. BOX 119 Goddard, KS 67052
JOHN HANDELL			
Valery Giebel	918-581-5500	vgiebel@paugetalk.com	1000 5TH ST., SUITE 900 TULSA, OK 74103
Kelly Boston	918-231-1385	kelly.boston@tksa.com	315 S BOWLER - Tulsa

October 11, 2017

[illegible]

OPENING STATEMENT OF WARREN AMERICAN OIL COMPANY, LLC

EPA hearing, Wednesday, October 11, 2017

Gentlemen:

My name is Doug Norton, speaking today on behalf of Warren American Oil Company, LLC in Docket No. SDWA-06-2017-1111 concerning the Bird Creek salinity issues being investigated by the Environmental Protection Agency ("EPA"). Warren American is grateful to the EPA for this opportunity to place into the record written expert reports and evidence which we believe conclusively exonerates Warren American from the allegations that it has "failed to confine injected fluids to the authorized injection zone" resulting in the contamination observed in Bird Creek.

Warren American has been in business for over seventy-five (75) years and enjoys an excellent reputation both inside and outside of the oil and gas community. This is the first time in Warren American's history where it has been involved in an EPA Hearing. Warren American is deeply committed to protecting the environment of Osage County while producing oil and gas for our own benefit and for the benefit of the Osage Nation.

Warren American has owned the Chapman lease since December, 2013, when it was acquired from Link Oil Company. Warren American has fully cooperated with the EPA in every aspect of this investigation from August, 2016 until the present date. We have turned over to the EPA all of our files and records pertaining to our injection wells and our production wells. We have devoted hundreds of man hours, internally investigating our own operations, in an attempt to arrive at an answer to this dilemma. We have periodically shut down our operations, conducted numerous diagnostic tests on

injection wells and producers, and monitored salinity and temperatures at various spots along Bird Creek over time. We have spent numerous hours discussing both the facts and theories with representatives of the EPA and representatives of the surface owners. We deeply value the input and efforts that the general public and the EPA have made with respect to this problem and pledge to continue to work with the agency and surface owners in the future.

With respect to the proposed Order that was sent to Warren American by the EPA on July 29, 2017, it is Warren American's opinion that the conclusions reached in the proposed Order as to Warren American's operations are factually and scientifically incorrect, and the data does not support the EPA's theory that the Mississippi Chat formation is over-pressured.

Warren American's opinion is based on the following observations:

1. The Mississippi Chat formation is not over-pressured. As a preliminary matter, we would note that of the three (3) injection wells operated by Warren American on the Chapman Lease, two of the wells (B-8 and B-9) are taking water on a vacuum and the third is operating at a very low injection pressure. It is difficult to understand how the EPA could arrive at the conclusion that injection wells that take water on a vacuum could lead to, or contribute to, the over-pressuring of the Mississippi Chat formation. In the aggregate, Warren American's producing operations bring both water and oil to the surface, separates the oil from the water, and then reinjects the water back into the same producing formation without adding any "make-up" water to replace the oil volume produced. This concept (or recycling operation) has been going on with respect to the Mississippi Chat reservoir at this location for more than 50 years. The result is that the

reservoir pressure in this Mississippi Chat formation is now less than the bottom-hole pressure was 50 years ago. Since the pressure within the Mississippi Chat has continuously declined over time, there is no scientific or factual basis for the conclusion that the Mississippi Chat has been or is "over-pressured". As a professionally registered petroleum engineer with forty years of experience, I can attest that it would be classified as a normally pressured reservoir.

To study this finding of the EPA, Warren American has engaged the services of Cobb and Associates Petroleum Engineers. Under Cobb's guidance, Warren American recently obtained measured bottom-hole injection pressures for all three of its injectors on the Chapman lease. A copy of the Cobb and Associates report is submitted along with this statement which concludes (A) the Mississippi Chat is not over-pressured; (B) that the Warren American injection wells are not injecting water in volumes, or at pressures, anywhere close to the fracture gradient of the Mississippi Chat formation; and, (C) that there is approximately 2400 feet of vertical elevation between the top of the Mississippi Chat formation and the bottom of Bird Creek at Monitoring Station No. 6; and (D) that 90 percent of the pressure drop (from the injection wells to the producers) occurs within 10 feet of the injectors and therefore there is insufficient reservoir pressure (even while water injection is occurring) to lift a column of fluid from the Mississippi Chat into the bottom of Bird Creek (as long as the water entering our injection wells at the surface actually enters the Mississippi Chat formation and does not channel up the backside of the casing).

2. Warren American's injected water is confined solely to the Mississippi Chat formation. Also submitted along with this statement is the Affidavit of our Vice-

President of Operations, Mr. John Burroughs. As Mr. Burroughs affidavit describes, Warren American has taken additional steps to conclusively prove that the water it is injecting into its injection wells is not escaping somewhere between the surface and the Mississippi Chat formation. This is evidenced primarily by three radioactive injection profile tests which Warren American recently caused to be run by Associated Wireline Service, Inc. of Healdton, Oklahoma. These tests, results of which are attached to Mr. Burroughs affidavit, conclusively show that all waters injected into the Warren American wells enter the Mississippi Chat formation and do not escape between the surface and the Mississippi Chat or channel up the outside of the wellbores. The Cobb Report, referenced previously, also concludes, based on these injection profiles, that the injected water is confined solely to the Mississippi Chat formation.

3. Warren American injection wells have not “recently” failed MIT tests. There has been insinuation that Warren American’s injection wells have “recently” failed MIT tests. This was alluded to in the public comments. Mr. Burroughs affidavit corrects the record with respect to these facts. A summary of Mr. Burroughs affidavit regarding these issues is as follows:

- A) The Warren American C-W4 well (sometimes referred to as the C-1 well) did fail an MIT test on November 18, 2014 at which time all injection of fluids was discontinued. The well was subsequently plugged in 2016 as witnessed by the EPA.
- B) The Warren American B-9 well failed an MIT on August 11, 2015. All injection was discontinued at that time. As Mr. Burroughs affidavit shows, efforts were made to repair the B-9 well which were ultimately

successful. Injection was re-commenced after the well successfully passed an MIT test on December 30, 2016. The B-9 well is currently taking water on a vacuum and injecting approximately 900 BWPD.

In summary, neither of these wells could have contributed to the pollution of Bird Creek which occurred in August, 2016 as neither had been in operation for a full year prior to the discovery at Monitoring Station No. 2. Also, neither had the type of failure that would permit injection into a shallow horizon.

Concurrent with our conclusion that Warren American is not responsible for the Bird Creek contamination, a separate likelihood has also been determined: that the contamination was a one-time event and there is no ongoing pollution into the creek. This topic is addressed in a second report, authored by Dr. Kerry Sublette, distinguished Professor of Environmental Engineering at the University of Tulsa. In addition to studying data provided by the EPA, Dr. Sublette walked the creek and supervised the measuring of salinity and temperature at several spots (beyond the EPA sondes) over time. Dr. Sublette's report is also being offered into the record today to support Warren American's observation that the salinity levels present in Bird Creek have declined over time, and are continuing to decline. This finding strongly supports the position that there is no ongoing pollution into the creek. In particular, the salinity levels at Monitoring Station No. 2, where initial reports found 80,000 parts per million of chlorides, have now fallen to below 1,000 parts per million-and continue to decline. Salinity also continues to fall at Monitoring Station No. 6, although the salinity measurements remain high in the deepest part of that pool. However, salinity readings 6" from the surface at Station No. 6

decrease rapidly to the 1500 ppm range. Dr. Sublette concludes that all observations of increased salinity can be explained by stratified flow and pool to pool transport of salts.

Another significant finding by Dr. Sublette is that the temperature anomalies observed at various depths of Bird Creek could readily be explained by solar heating of the dense saline layers. Therefore, communication with the creek and a deeper stratum would not be necessary to explain elevated temperatures at deeper, high salinity locations.

So that the record is clear, Warren American was requested to voluntarily shut-in all three of its injection wells on at least two occasions. The first time was from June 9 – June 16, in conjunction with the shut-in of all three of the operators' wells, at the EPA's request. The second shut-in began on August 9, to cooperate with the EPA's Proposed Administrative Order. From that date, for approximately thirty (30) days, Warren American's production facilities were completely shut down. As should be noted for the record, Warren American has no alternative source to take produced water off of the Chapman lease. Also, Warren American has been told by EPA personnel that no new permits, to drill a disposal well further to the north or to dispose of our produced water into different formations, will be approved. Without disposal wells, Warren American cannot produce the Chapman lease.

As a consequence of the foregoing, and in an effort to continue to gather scientific data, Warren American decided to reactivate its operations following the thirty (30) day shut-in. The reactivation occurred on September 8, 2017. From that date, Warren American has obtained readings from both Monitoring Station No. 2 and Monitoring Station No. 6 with the consent of the surface owner and with the knowledge of the EPA.

Dr. Sublette addresses those readings in his report. The bottom line is that the salinity levels continue to decline or remain steady, even after the Warren American's wells have been re-activated. This certainly suggests that the Warren American wells have not, and do not, contribute to the salt water that entered Bird Creek in August, 2016, nor does it appear that there is any current inflow of saltwater from any source.

In conclusion, it is Warren American's position that it, at all times, operated its wells in compliance with the terms of its underlying permits. We believe that the initial photographic evidence of oil and oil sheens in the creek in August, 2016, and the absence of any reported oil sheens subsequent to August, 2016, strongly substantiate that this was a one (1) time event. The gradual decline of the salinity of the water remaining in the creek also supports our conclusion that the pollution is not currently reoccurring. This is particularly true with respect to Warren American's wells which were voluntarily shut-in for an extended period of time. The evidence shows that prior to the Warren American shut-in, during the shut-in, and after injection activities were resumed, salinity levels within Bird Creek all continued a gradual and steady decline.

Warren American concurs with the recommendation in Dr. Sublette's Report, that the high salinity water in Monitoring Station No. 6 be drained; two or three times, if necessary. The salinity at that Station should continue to be monitored during this process.

Further, Warren American believes that the EPA's proposed order to permanently discontinue disposing of produced water into the Mississippi Chat is arbitrary and capricious, and is not supported by the data. As noted above, such an order would likely lead to an inability to produce the Chapman lease. Other alternatives are available, at

least on an interim basis, to monitor the situation. These would include: (1) lowering the allowed maximum injection pressure on the Warren American injection wells; (2) requiring an annual or biannual MIT test on Warren American injection wells; (3) conducting weekly monitoring and reporting of casing pressure, in addition to the current tubing pressure; and (4) requiring weekly monitoring of the salinity levels within Bird Creek for an extended period of time.

Warren American has not yet received all of the documents that it has requested from the EPA through various Freedom of Information Act requests. We respectfully request that we be provided adequate time to review and respond to this information once it is received.

Warren American is of the firm belief that its activities were not the cause of the observed pollution. Our expert reports show that the proposed order, as directed to Warren American, is not supported by scientific evidence and represents a finding of “guilt by association” that is not warranted. We honor our reputation for honesty and integrity in all matters pertaining to our operations and the proposed order deprives us of the ability to prove our innocence. We would strongly urge the EPA not to go forward with the proposed Administrative Order while data is indicating that no further contamination is occurring.

Attachments:

- 1) Report of Cobb & Associates
- 2) Report of Dr. Kerry Sublette
- 3) Affidavit of John D. Burroughs, P.E.

RESERVOIR ENGINEERING STUDY
OF THE
MISS CHAT RESERVOIR
OSAGE COUNTY OKLAHOMA

PREPARED FOR
WARREN AMERICAN OIL COMPANY

OCTOBER 2017

WILLIAM M. COBB & ASSOCIATES, INC.

Worldwide Petroleum Consultants

WARREN
AMERICAN

2

WILLIAM M. COBB & ASSOCIATES, INC.

Worldwide Petroleum Consultants

12770 Coit Road, Suite 907
Dallas, Texas 75251(972) 385-0354
Fax: (972) 788-5165
E-Mail: office@wmcobb.com

October 6, 2017

Mr. Doug Norton
Warren American Oil Company
6585 South Yale, Suite 800
Tulsa, Oklahoma 74136Re: Miss Chat Reservoir
Osage County, Oklahoma

Dear Mr. Norton:

At your request, I have reviewed two technical reports and various data items associated with waterflood operations in the Miss Chat reservoir in Osage County Oklahoma. My study addresses allegations that operators of water injection wells in the Miss Chat reservoir have failed to contain the water to the injection interval resulting in brine contamination at the surface, specifically in Bird Creek. The two technical reports which I have reviewed are:

1. "Bird Creek Investigation and Injection Well Response Action Plan", August 4, 2017, prepared by the US EPA Dallas office
2. "Comment Letter on Administrative Orders: SDWA-06-217-1110 (Jireh Resources, LLC); SDWA-06-2017-1112 (Novy Oil and Gas, Inc. (Grayhorse Operating, LLC)), and SDWA-06-2017-1111 (Warren American Company, LLC), September 1, 2017, prepared by Bill Biehl, PG, EH&S Manager, BEPCO, L.P. (on behalf of Osage Land & Cattle Co.)

Field History

The Miss Chat reservoir, also known as the "Blackland Pool" was discovered in 1922, according to a memo and technical data compiled by Mr. David Roberts¹, a petroleum engineering consultant. Very few wells were drilled until field wide development commenced in 1953. From 1953 to 1966, all produced water was disposed of into the Layton sand. A field-wide cooperative waterflood was implemented in 1966 by Texaco, Sun, and K-M Oil Co. This cooperative unit covered nine quarter sections, and produced water was re-injected into the Miss Chat reservoir. There is no evidence that makeup water was ever used on the Chapman lease.

¹ Memo dated October 3, 2017, by David Roberts.

Mr. Doug Norton
October 6, 2017
Page 2

This appears to be corroborated in a 1976 report by Keplinger and Associates, Inc.² which states that reservoir withdrawals have exceeded water injection.

Oil production for the specific Warren American Oil Company (WAOC) Chapman lease is unknown. However, the combined Jireh McComb and WAOC Chapman leases have produced about 4.1 million barrels of oil. Produced and injected water volumes are unknown. What is known, however, is that total water injection is less than total water production.

WAOC purchased the Chapman lease properties in December, 2013, from Link Oil & Gas. As shown on Exhibit 1, the Chapman lease borders the Jireh McComb lease on the east and south. Grayhorse operates another Miss Chat property about a mile southeast of the Chapman lease.

Current Reservoir Pressure

We know that only a portion of the produced volumes have been returned to the Miss Chat reservoir, which should have resulted in gradual pressure depletion over time. Current measurements of bottom-hole pressure (BHP) confirm this fact.

There are no early BHP readings available for the Miss Chat reservoir. However, original BHP (BHP_i) can be estimated using the following equation:

$$\text{BHP}_i = \text{Avg. Depth} * 0.433 \text{ psi/ft. (normal pressure gradient)}$$

$$\text{BHP}_i = 2500 \text{ ft.} * 0.433 \text{ psi/ft.}$$

$$\text{BHP}_i = 1082 \text{ psi}$$

WAOC has conducted recent BHP surveys in producing and injection wells, as shown in Exhibit 2. This test program indicates that the current pressure in the Miss Chat reservoir is between 900 and 950 psi, which is lower than original BHP. Significantly, this pressure *is not* sufficient to bring a column of brine water to the surface. In fact, the standing fluid levels measured in these tests ranged from 500 feet to 737 feet below the surface. Neither the EPA report nor the Osage Land and Cattle report dispute this finding. However, the EPA claims that injection operations could force water to the surface (page 2, bullet 4).

In Mr. Biehl's report, he spends considerable time and text showing what allowable injection surface pressures are and what the calculated downhole pressure would be, *IF* the maximum allowed surface pressures were used (see Reservoir Engineering – Allowable Injection Pressure section, page 10). This is irrelevant to the WAOC wells, which are operated with surface pressures as shown from recent tests:

1. Well B7 > Injecting 1146 BWPD with **135 psi surface pressure**. Measured BHP while injecting was 1285 psig at 2517 feet (0.511 psi/ft.). When shut-in, the surface **went on a vacuum** in 20 seconds. BHP dropped from 1285 psig to 1086 psig in 15 minutes and was still dropping when the gauges were pulled.

² An Evaluation of Interests Owned by K-M Oil Company, Blackland Pool, Osage County, Oklahoma as of July 1, 1976.

Mr. Doug Norton
 October 6, 2017
 Page 3

2. Well B8 > injecting 858 BWPD with 27" ***vacuum*** at the surface. Measured BHP while injecting was 1149 psig at 2546 feet (0.451 psi/ft.).
3. Well B9 > injecting 1168 BWPD with 27" ***vacuum*** at the surface. Measured BHP while injecting was 1160 psig at 2557 feet (0.454 psi/ft.).

The tests shown above clearly show that bottom hole injection pressures are not excessive. In fact, this is one of the most "gentle" waterfloods, in terms of bottom-hole injection pressure gradient, that I have seen in my 35+ year career.

The average injection pressure gradient in the WAOC wells is 0.472 psi/ft. This is sufficient to bring brine water close to the surface ***IF*** there is a high conductivity breach, right at the wellbore. However, WAOC has run mechanical integrity tests (MIT's) and injection profile surveys which do not indicate any such breach. Therefore, in order for injected brine to reach the surface, it must first travel through the reservoir to a nearby well with compromised integrity to find a path to the surface. In doing so, the injected water loses most of its energy (pressure) within a few feet of the injection well, leaving it incapable of lifting a column of water to the surface. Exhibit 3 is cartoon diagram of the theoretical pressure distribution in an oil reservoir from an injection well to a producing well. I have placed actual pressure values on this diagram; however, the shape of the pressure trend near the wells is implied from theory.

To further illustrate this point, I have made a calculation of the pressure drop from an injector to a point 660 feet away (10 acre well spacing) for a reservoir with a permeability value of 50 md. Results of this calculation are shown graphically in Exhibit 4. Note on Exhibit 4, that more than 90 percent of the pressure drop from the injector to the producer occurs within 10 feet of the injection well. Again, this indicates that any pathway more than a few feet from the injection well cannot deliver water with sufficient pressure to bring it close to the surface.

Miss Chat Frac Gradient

In the Osage Land and & Cattle Co. report, Mr. Biehl speculates that the frac gradient for the Miss Chat reservoir will likely be low, perhaps around 0.5 psi/foot due to the rock being a "soft, weathered chert". In my experience this 0.5 psi/foot frac gradient is too low. In fact, a 1967 frac treatment report for the K-M Chapman F-1 well shows a frac gradient of about 0.70 psi/foot, which I find to be quite normal. Using that value, the surface pressure required to frac the Miss Chat reservoir would be calculated as follows:

$$\text{Frac Pressure (FP)} = \underline{\text{BHP} = \text{SURFP} + \text{HP} - \text{FP}} \text{ (Biehl equation, page 10)}$$

Rearranging this equation to solve for the surface pressure (Max SURFP) at which the Miss Chat will frac:

$$\text{Max SURFP} = \text{BHP (frac pressure)} - \text{HP} + \text{FP}$$

$$\text{Max SURFP} = (0.70 * 2500) - (2500 * 0.433 * 1.07) + 49$$

$$\text{Max SURFP} = 641 \text{ psi}$$

Mr. Doug Norton
October 6, 2017
Page 4

As shown in the previous section, WAOC well B7 is injecting with 135 psi surface pressure, while the B8 and B9 wells take water on a vacuum. Clearly, none of the WAOC injection wells are injecting at or above the frac gradient. Conversely, all three wells are injecting *well under* the frac gradient.

Fluctuations in TDS Measurements

On page 6 of the EPA report, in bullet 4, the EPA contends that fluctuations in the TDS readings are due to injection pump cycling. This contention is technically flawed in at least two ways:

1. Injection pumps cycling would send pressure pulses through the reservoir. Note that these pressure pulses diffuse with distance from the injector and are almost imperceptible a short distance from the injector.
2. Injection pump cycling would have no impact on the chemical composition of the water being produced at a distant location.

It is very likely that the fluctuating TDS values cited by the EPA are due to temperature fluctuations when the samples were taken. Exhibit 5 is a graph of TDS and temperature measurements from MP6. Note the cyclic behavior of both temperature and TDS. The dark blue border on Exhibit 5 shows the time period when field injection operations were shut down. Exhibit 6 shows this same data with the time scale focused on the period when injection operations were shut-in. Note that the temperature and TDS values cycle on a 24-hour period. This is simply the effect of daytime heating and nighttime cooling on the constant composition water in the pool at MP6. This data provides no evidence of any link between injection well operations and surface water quality in Bird Creek.

Exhibit 7 presents TDS data for stations 2 and 6 obtained by the EPA, Bureau of Indian Affairs (BIA), and WAOC. Cumulative rainfall is also displayed on this graph. This graph shows that with passing time and periodic rainfall, the TDS readings at both stations 2 and 6 are declining. Upstream station 2 has returned to normal conditions. Downstream station 6, which is deeper than station 2, shows a declining TDS trend. This graph clearly shows that there is no ongoing release of Miss Chat water into Bird Creek.

Conclusions

1. Analysis of available data indicates that the release of brine water into Bird Creek in August of 2016 was a one-time event.
2. The Miss Chat reservoir has been gradually voided over time, causing a gradual reduction in pressure, from an original value of about 1082 psi to a current value of about 925 psi.
3. The current average Miss Chat reservoir pressure is not sufficient to bring reservoir fluids to the surface.
4. Current reservoir pressure can bring a column of brine water no higher than about 500 feet from the surface. This is corroborated by recent BHP and fluid level measurements.
5. The three WAOC injection wells have passed MIT tests and all have had injection profile surveys run, indicating that injected fluids are not escaping the reservoir at these wells.

Mr. Doug Norton
October 6, 2017
Page 5

6. Current bottom-hole injection pressures at the WAOC wells are well below the Miss Chat frac gradient of about 0.70 psi/foot.
7. If fluids are escaping the reservoir any distance from the injection wells, there will be insufficient pressure to bring fluids higher than about 500 feet from surface.
8. Fluctuations (noise) in the TDS and temperature readings cited by the EPA are simply cyclic events associated with temperature variations over each 24 hour period. These are normal and to be expected, and are not an indication of communication from injection wells to the surface.

I appreciate the opportunity to assist Warren American Oil Company in this matter. Should you have any questions regarding the subject report or conclusions, please do not hesitate to contact me.

Sincerely,

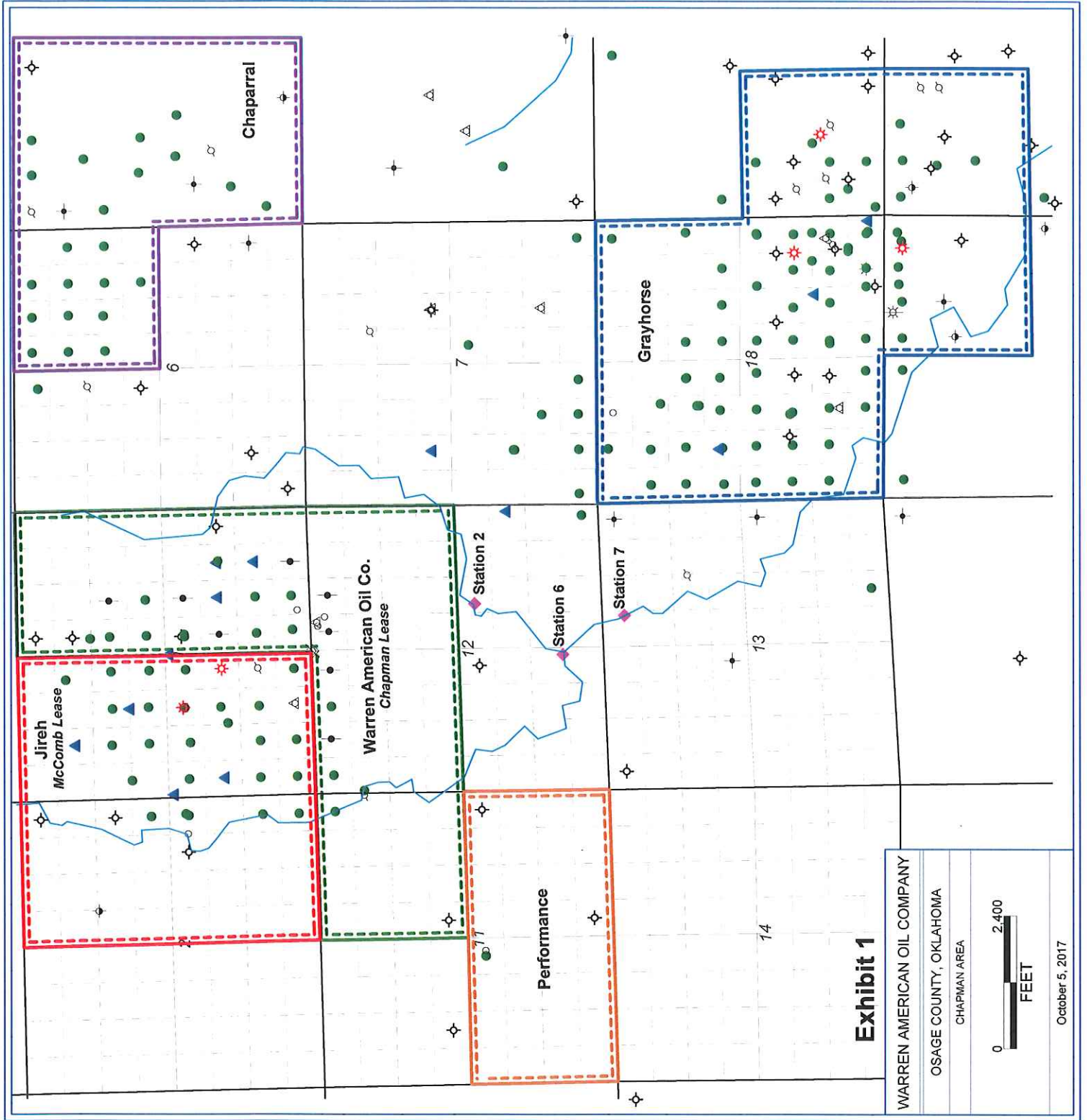
WILLIAM M. COBB & ASSOCIATES, INC.
Texas Registered Engineering Firm F-84


Frank J. Marek, P.E.
President



FJM: ar
Attachments
M/Warren America/Miss chat Reservoir 100617

EXHIBITS



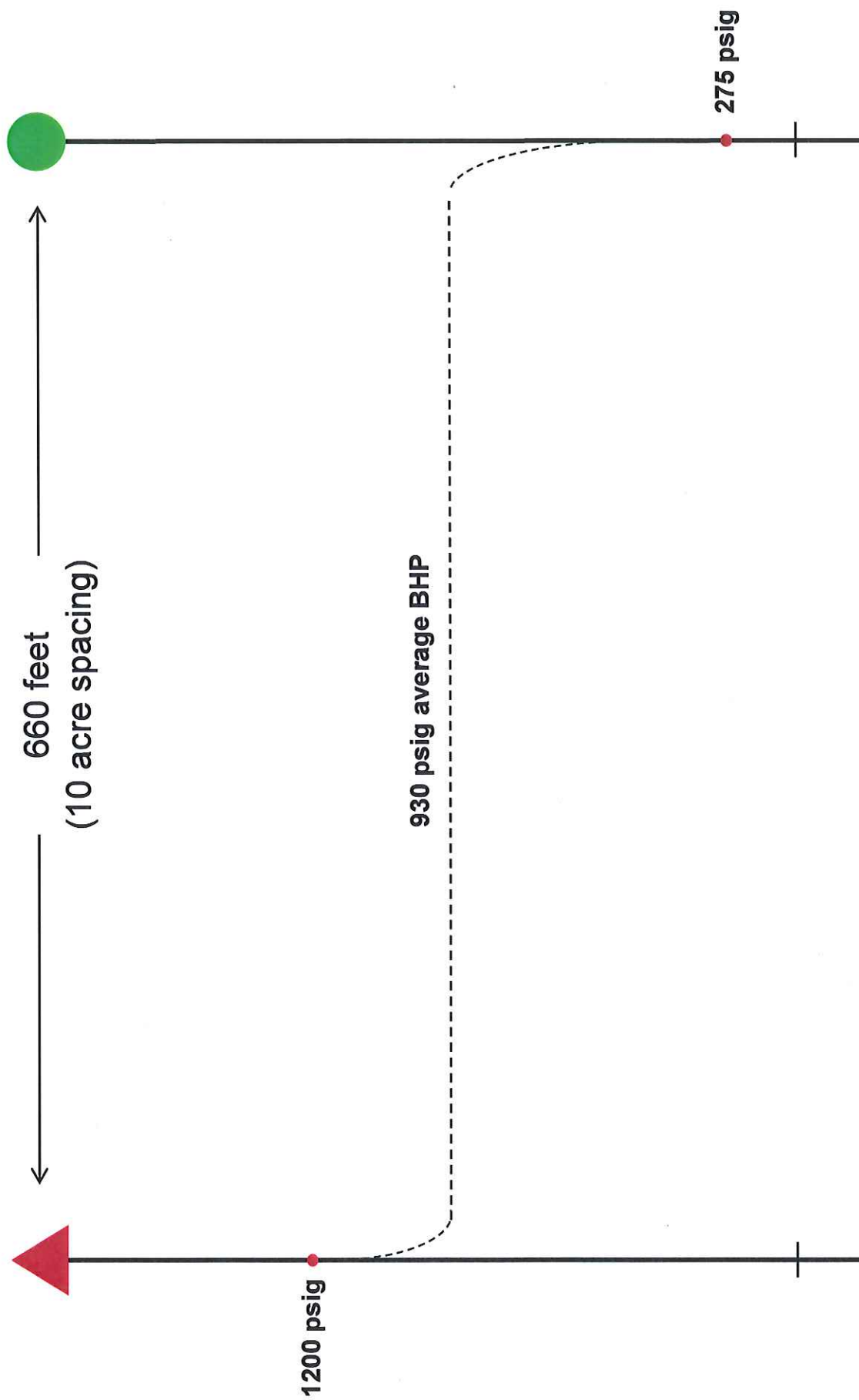
*Warren Americal Oil Company**Recent Chapman Lease BHP Data*

Well	Well Type	Date	MPOP	BHP, psig	BHT	fluid level ft. from Surf.	type of test
B7	injector	08/31/17	2517	898	N/A	631	acoustic F.L.
B8	injector	08/31/17	2546	932	N/A	590	acoustic F.L.
B8	injector	09/07/17	2546	953	107	592	wireline gauge
B9	injector	08/31/17	2556	871	N/A	737	acoustic F.L.
B9	injector	09/07/17	2556	904	113	728	wireline gauge
E3	producer	09/07/17	2497	973	122	506	wireline gauge
E3	producer	09/07/17	2497	885	N/A	500	acoustic F.L.
				Avg. =		612	

overall average = 917

wireline BHP Avg. = 943

Theoretical Pressure Distribution – Injector to Producer



Oil Reservoir Reservoir with Perm. = 50 md.

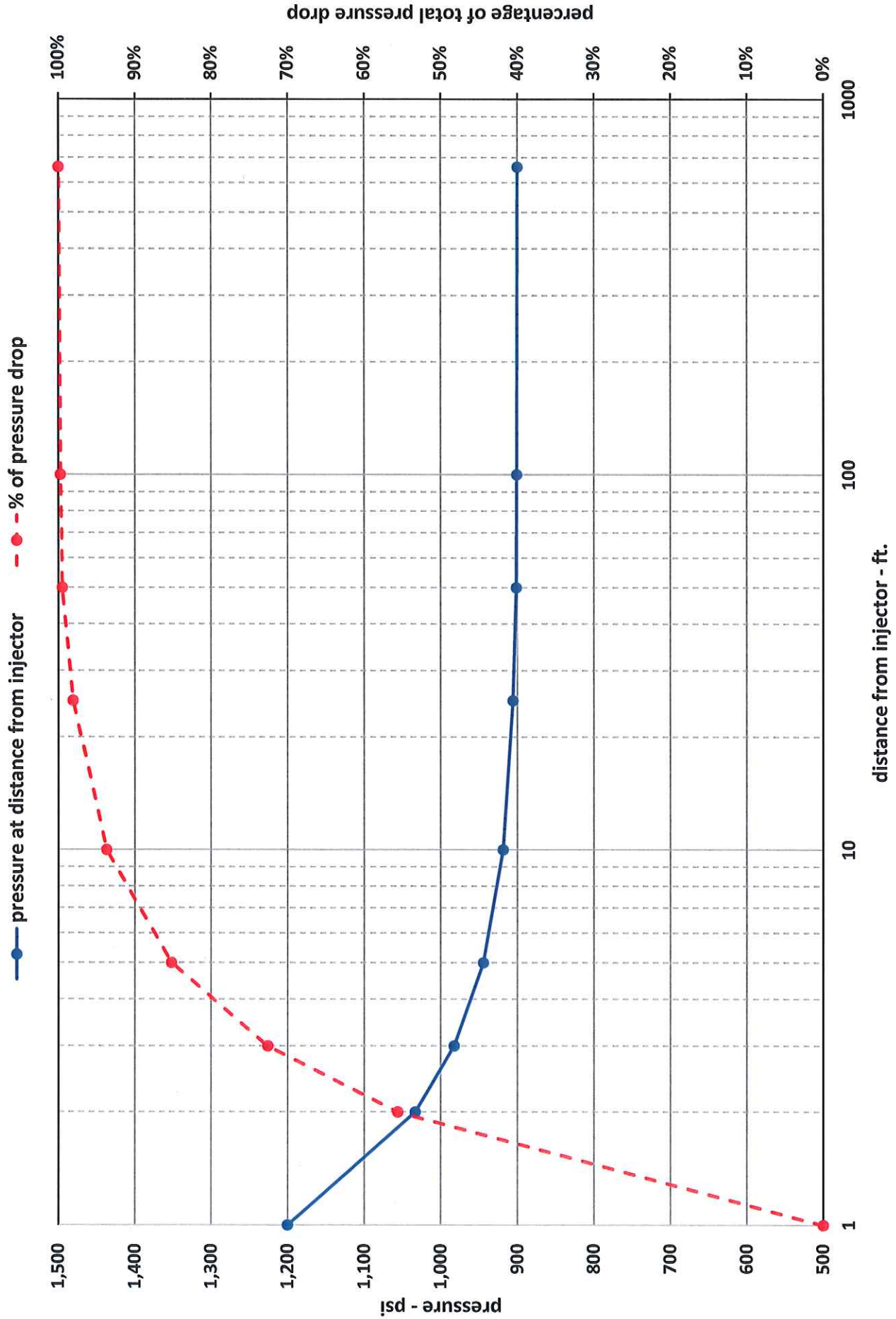
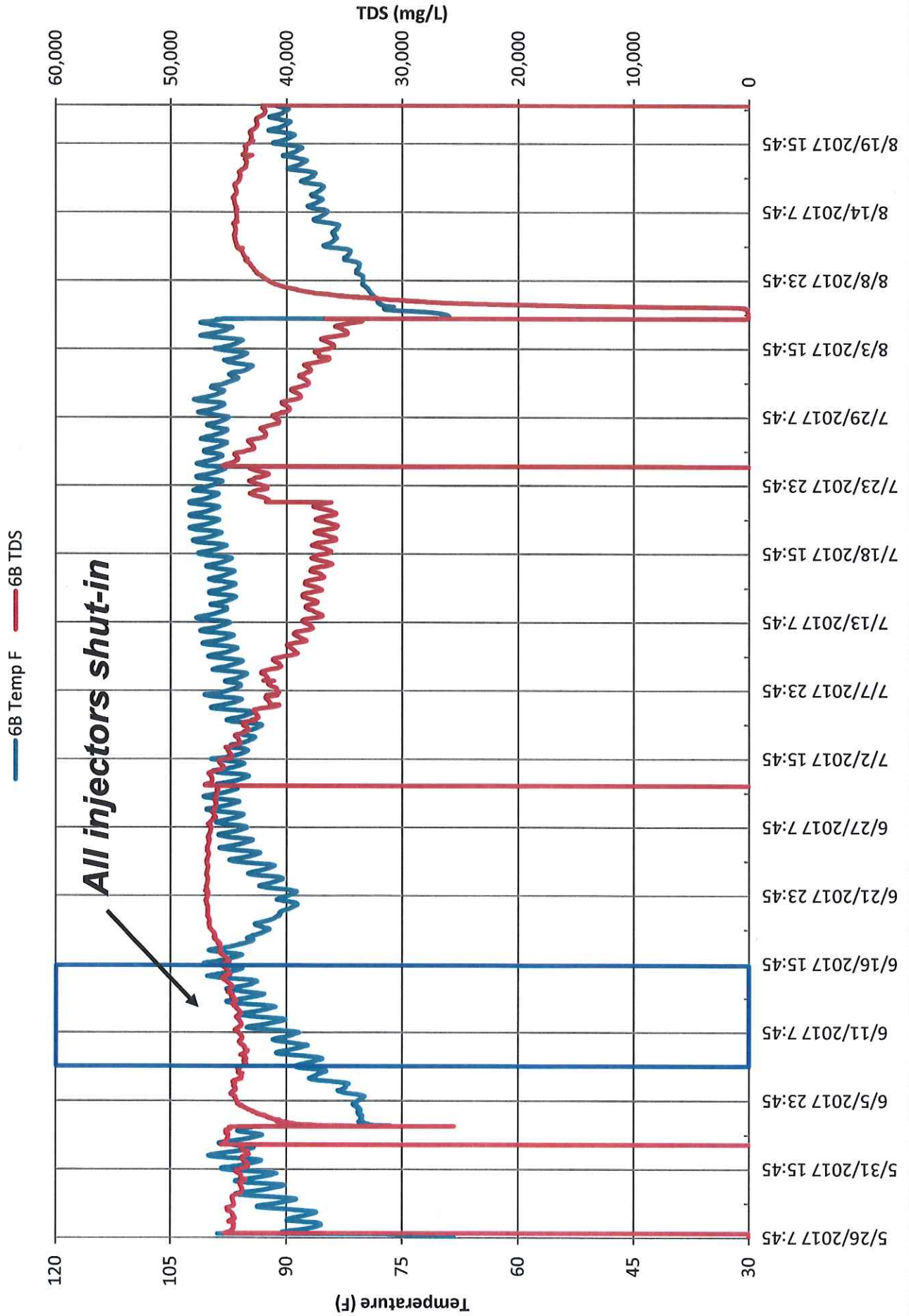


Exhibit 5

William M. Cobb & Associates, Inc.

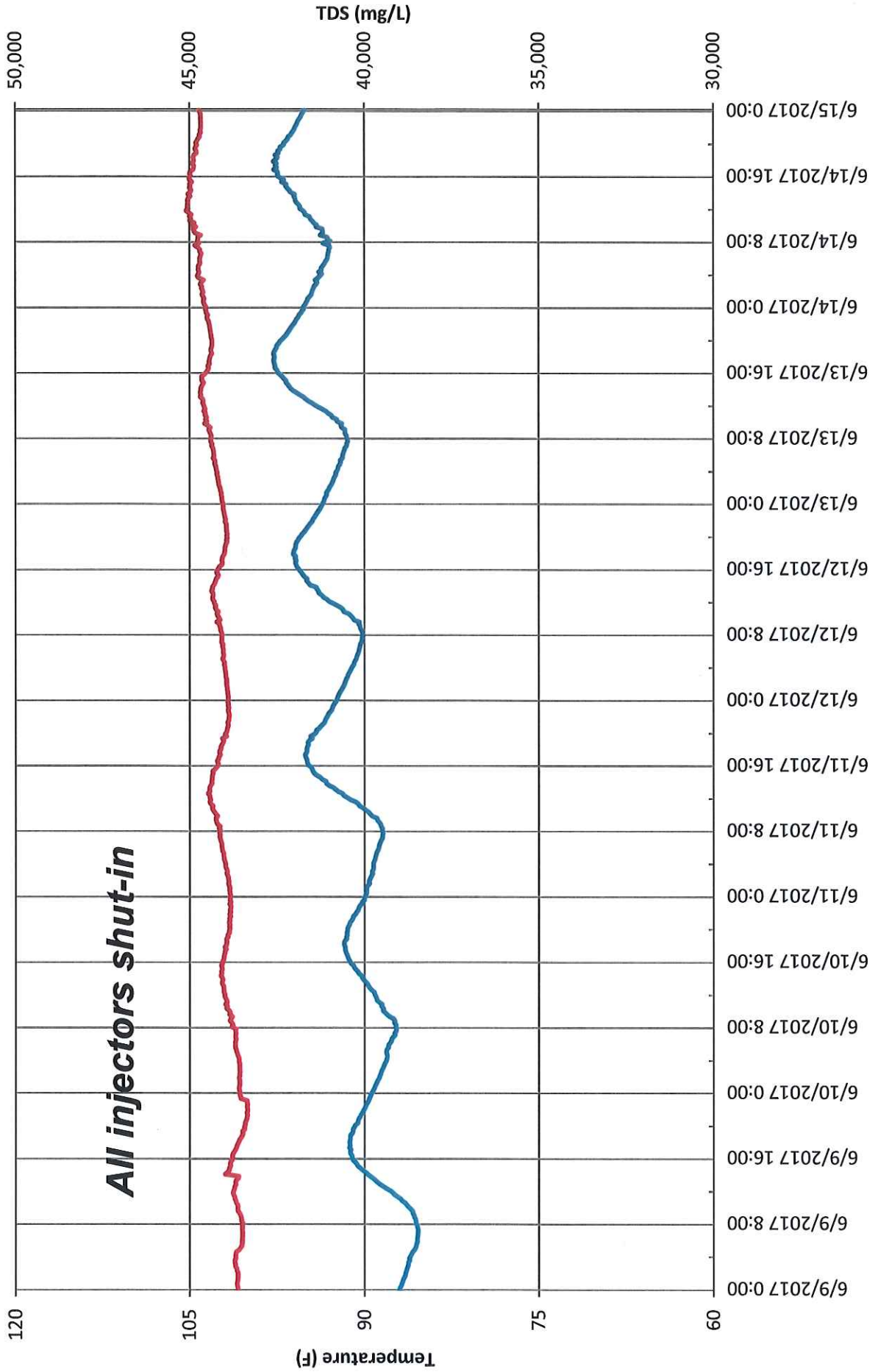
TDS Measurements - MP6B



TDS Measurements - MP6B

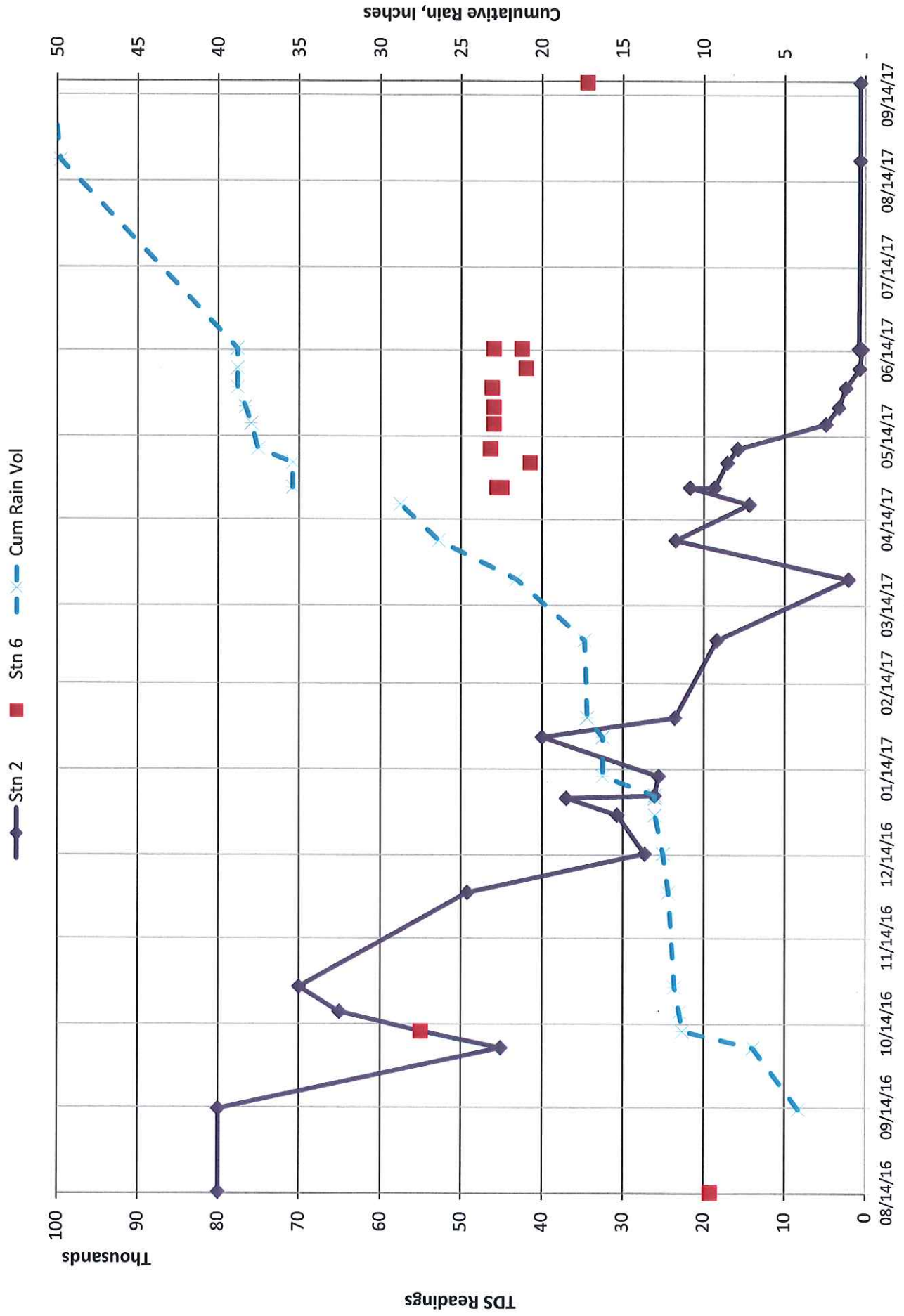
06/09/2017 - 06/14/2017

6B Temp F 6B TDS



All injectors shut-in

Bird Creek - TDS Readings



UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY, REGION 6
DALLAS, TEXAS

In the matter of:	§	Docket No. SDWA-06-2017-1111
Warren American Oil Company, LLC	§	RESPONDENT'S ANSWER TO
RESPONDENT	§	PROPOSED ADMINISTRATIVE ORDER
	§	AND REQUEST FOR HEARING
	§	
	§	

AFFIDAVIT OF JOHN D. BURROUGHS

STATE OF OKLAHOMA)
) ss.
COUNTY OF TULSA)

COMES NOW John D. Burroughs, upon his oath and being duly sworn alleges and states as follows:

1. That I am a resident of Tulsa County, Oklahoma, am over the age of 21 years and I have personal knowledge of the facts set forth in this Affidavit.

2. That I am a practicing petroleum engineer with over 37 years of experience in the operation and production of oil and gas properties in Oklahoma.

3. That I currently serve as the Vice-President, Operations, of Warren American Oil Co. ("WAOC").

4. That I, or employees of WAOC working under my supervision and control, have caused salinity readings to be made on "Bird Creek" on September 18, 2017 and on October 4, 2017. The results of these readings are contained on Exhibit "A" attached hereto and made a part hereof. These readings were taken by WAOC after reactivating its disposal wells on the Chapman lease on or about September 8, 2017.

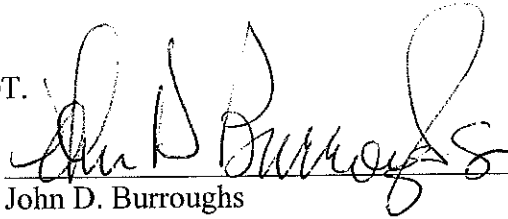
WARREN
AMERICAN
3

5. That in my capacity as Vice-President of Operations, I retained Associated Wireline Service, Inc. to run injection profiles on Warren American's B-7, B-8 and B-9 disposal wells located on the Chapman lease on September 12, 2017 and October 2, 2017. The results of these injection profiles (attached hereto as Exhibit B-1, B-2 and B-3) show that the fluid going into the subject well is going into the perforations of said wells and into the Mississippi Chat formation. None of the injection profiles indicate that any fluid is channeling upwards behind pike.


6. That in my capacity as Vice-President of Operations, employees of WAOC under my supervision and control, witnessed the failure of a Mechanical Integrity Test (MIT) on the Chapman C-W4 and the Chapman B9 wells. The C-W4 failed its test on November 18, 2014 at which time the well was injecting approximately 600 BWPD with pressure ranging from 20" vacuum to 50 PSIG. Injection was immediately stopped. Subsequent wellwork on the well found a hole in a joint of tubing. After pressure testing the tubing and replacing several joints the packer and tubing was re-run into the well but again the well failed its MIT. The well was temporarily abandoned and fluid level monitoring occurred as per EPA regulations. A decision to plug the well was made in November 2016 and the well was plugged per EPA instructions and witnessed by EPA personnel. The B9 well failed its MIT on August 11, 2015 and injection was discontinued. The tubing was pulled and several leaks in the threads were discovered which were then replaced. The casing was tested from 900' to the surface and held pressure but the well again failed to pass its MIT as the casing pressure slowly bled off more than the allowable amount when the entire casing was pressure tested. The well was temporarily abandoned and fluid level monitoring occurred. The well was then re-worked and passed its MIT in December

2016 and injection began on December 30, 2016. The well is presently taking water at approximately 900 BWPD on a vacuum.

FURTHER AFFIANT SAYETH NOT.

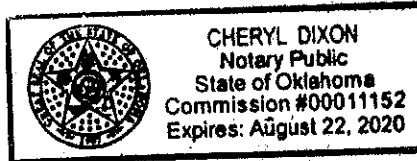

John D. Burroughs

Subscribed and sworn to before me this 10th day of October, 2017.


Notary Public

My Commission Expires:

8/22/20
#11152



L:\1063.38.Affidavit

Bird Creek - TDS Readings - Taken by Warren American Oil

All readings taken with a YSI Salinity Meter

	Sept 18, 2017		October 4, 2017				
	TDS, ppm	Depth	TDS, ppm	Temp, *C	SC, uS	Salinity, PPT	Estimated Depth to Btm
EPA Monitoring Stn 2	501						
EPA Monitor Stn 6	34,360	Bottom	34,800	28.7	53600	33.0	9'
EPA Monitor Stn 6		6" below Surf	1,670	23.3	2570	1.4	
10' Upstream Stn 6		Bottom	34,790	29.6	53500		9'
10' Upstream Stn 6		6" below Surf	1,674	23.2	2578		
20' Upstream Stn 6	32,970	Bottom	33,930	28.8	52400		8'
20' Upstream Stn 6		6" below Surf	1,609	23	2484		
50' Upstream Stn 6	4,444	Bottom	18,890	26.8	30320		7'
50' Upstream Stn 6		6" below Surf	1,640	23	2521		
10' Downstream Stn 6	33,780	Bottom	35,220	29.1	53800		8'
10' Downstream Stn 6	1,519	6" below Surf	1,644	23.2	2534		
20' Downstream Stn 6		Bottom	32,750	24.4	50100		5'
20' Downstream Stn 6		6" below Surf	1,676	22.9	2548		
50' Downstream Stn 6	2,695	Bottom	1,726	22.9	2643		1'
50' Downstream Stn 6		6" below Surf	1,696	22.8	2610		
By low water crossing EPA Monitor Stn	3,263	Bottom	3,742	22.3	5760		
By low water crossing EPA Monitor Stn		6" below surf	3,181	22.4	4900		
By low water crossing - 25' upstream		Bottom	3,690	22.4	5680		
By low water crossing - 25' upstream		6" below surf	3,399	22.2	5290		
By low water crossing - 50' upstream		Bottom	3,412	22.2	5050		
By low water crossing - 50' upstream		6" below surf	3,215	22.2	4930		
By low water crossing - 25' downstream		Bottom	3,820	22.3	5880		
By low water crossing - 25' downstream		6" below Surf	3,170	22.3	4867uS		
By low water crossing - 50' downstream		Bottom	3,516	22.4	5380		
By low water crossing - 50' downstream		6" below Surf	3,152	22.4	4523		

Exhibit "A"

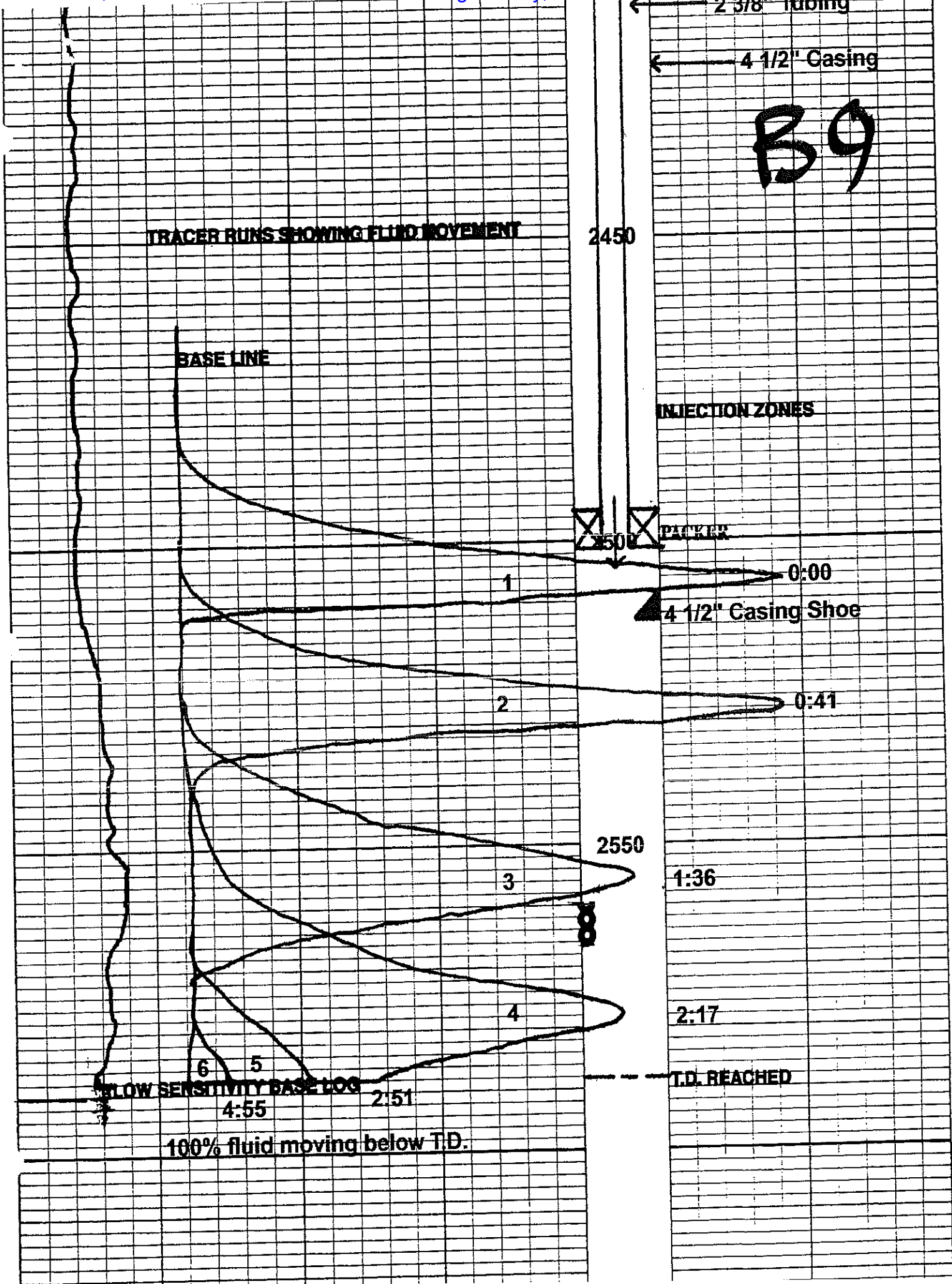
ASSOCIATED WIRELINE SERVICE. Inc.

580-229-0731 • Box 906 • Healdton, Oklahoma 73438

Exhibit "B-1"

FILING NO.	COMPANY <u>WARREN AMERICAN OIL CO., LLC</u>					
	WELL <u>CHAPMAN #B-9</u>					
	FIELD <u>N/A</u>					
	COUNTY <u>OSAGE</u>	STATE <u>OK.</u>				
LOCATION		TYPE SERVICES: INJECTION PROFILE				
SEC <u>1</u>	TWP <u>27N</u>	RGE <u>7E</u>				
PERMANENT DATUM _____ ELEV. _____		ELEV K.B. _____				
LOG MEASURED FROM _____ FT ABOVE PERM DATUM		D.F. _____				
DRILLING MEASURED FROM _____		G.L. _____				
DATE	<u>9/12/2017</u>	INJECTION PRESSURE _____ RATE <u>877 BD</u> FLUID <u>WATER</u> ISOTOPE <u>I-13</u> 8 DAY HALF LIFE				
RUN NO.	<u>ONE</u>					
TYPE LOG	<u>INJECTION PROFILE</u>					
DEPTH-DRILLER	<u>2586 PBTD</u>					
DEPTH-LOGGED	<u>2588</u>	CASING AND TUBING RECORD				
BOTTOM LOGGED INTERVAL	<u>2588</u>					
TOP LOGGED INTERVAL	<u>2400</u>					
TYPE FLUID IN HOLE	<u>WATER</u>					
LEVEL	<u>~~~~~</u>	SIZE	WGT	TYPE	FROM	TO
RECORDING SPEED	<u>25'/MIN.</u>	<u>5 1/2"</u>	<u>11.6#</u>	<u>S.T.</u>	<u>0</u>	<u>260</u>
TOOL SIZE	<u>1"</u>	<u>4 1/2"</u>			<u>0</u>	<u>251</u>
RECORDED BY	<u>COX</u>	<u>2 3/8"</u>			<u>0</u>	<u>250</u>
WITNESSED BY						
PERFORATIONS		<u>2560-67</u>				
REMARKS:		<u>SEE NOTE BELOW.</u>				

Exhibit "B-1"



PERCENT PER FOOT

WARREN AMERICAN OIL CO., LLC

CHAPMAN #B-9

N/A FIELD

OSAGE CO., OK.

CHANNEL

SLOTS

[illegible]

ASSOCIATED WIRELINE SERVICE. Inc.

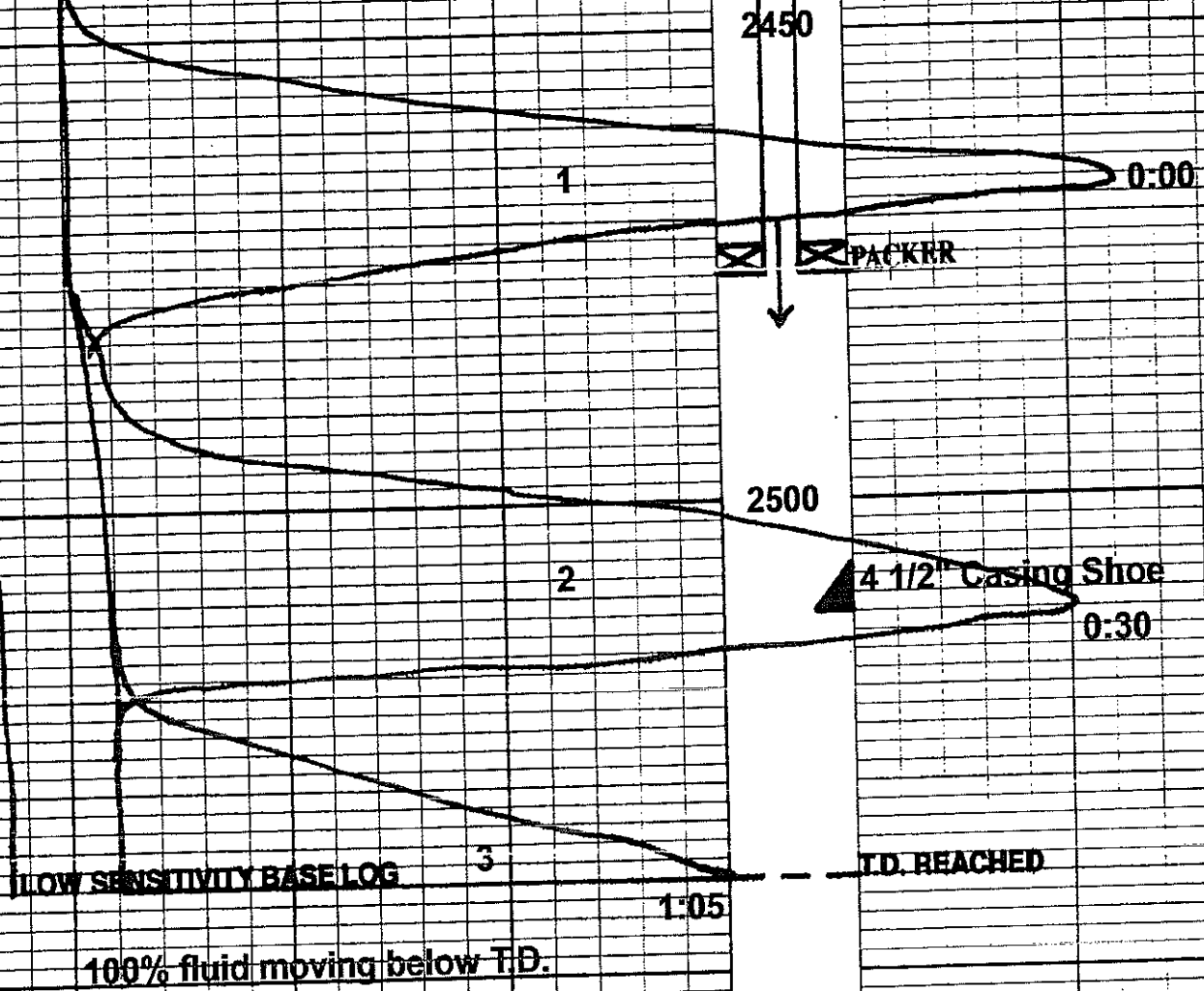
580-229-0731 • Box 906 • Healdton, Oklahoma 73438

Exhibit "B-2"

FILING NO.	COMPANY <u>WARREN AMERICAN OIL CO., LLC</u>					
	WELL <u>CHAPMAN #B-8</u>					
	FIELD <u>N/A</u>					
	COUNTY <u>OSAGE</u>				STATE <u>OK.</u>	
LOCATION						TYPE SERVICES: INJECTION PROFILE
SEC <u>1</u> TWP <u>27N</u> RGE <u>7E</u>						
PERMANENT DATUM _____ ELEV. _____				ELEV. K.B. _____		
LOG MEASURED FROM _____ FT ABOVE PERM DATUM				D.F. _____		
DRILLING MEASURED FROM _____				G.L. _____		
DATE	<u>9/12/2017</u>				INJECTION	
RUN NO.	<u>ONE</u>				PRESSURE <u>0</u>	
TYPE LOG	<u>INJECTION PROFILE</u>				RATE <u>885 BD.</u>	
DEPTH-DRILLER	<u>2575 PBT/D</u>				FLUID <u>WATER</u>	
DEPTH-LOGGED	<u>2540</u>				ISOTOPE <u>I-131</u>	
BOTTOM LOGGED INTERVAL	<u>2540</u>				8 DAY HALF LIFE	
TOP LOGGED INTERVAL	<u>2350</u>					
TYPE FLUID IN HOLE	<u>WATER</u>		CASING AND TUBING RECORD			
LEVEL	~~~~~	SIZE	WGT	TYPE	FROM	TO
RECORDING SPEED	<u>25'/MIN</u>	<u>5 1/2"</u>			<u>0</u>	<u>2591</u>
TOOL SIZE	<u>1"</u>	<u>4 1/2"</u>	<u>10.5#</u>		<u>0</u>	<u>2512</u>
RECORDED BY	<u>COX</u>	<u>2 3/8"</u>		<u>S.T.</u>	<u>0</u>	<u>2476</u>
WITNESSED BY						
PERFORATIONS		<u>2540-52</u>				
REMARKS:		<u>SEE NOTE BELOW.</u>				

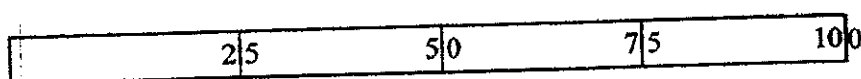
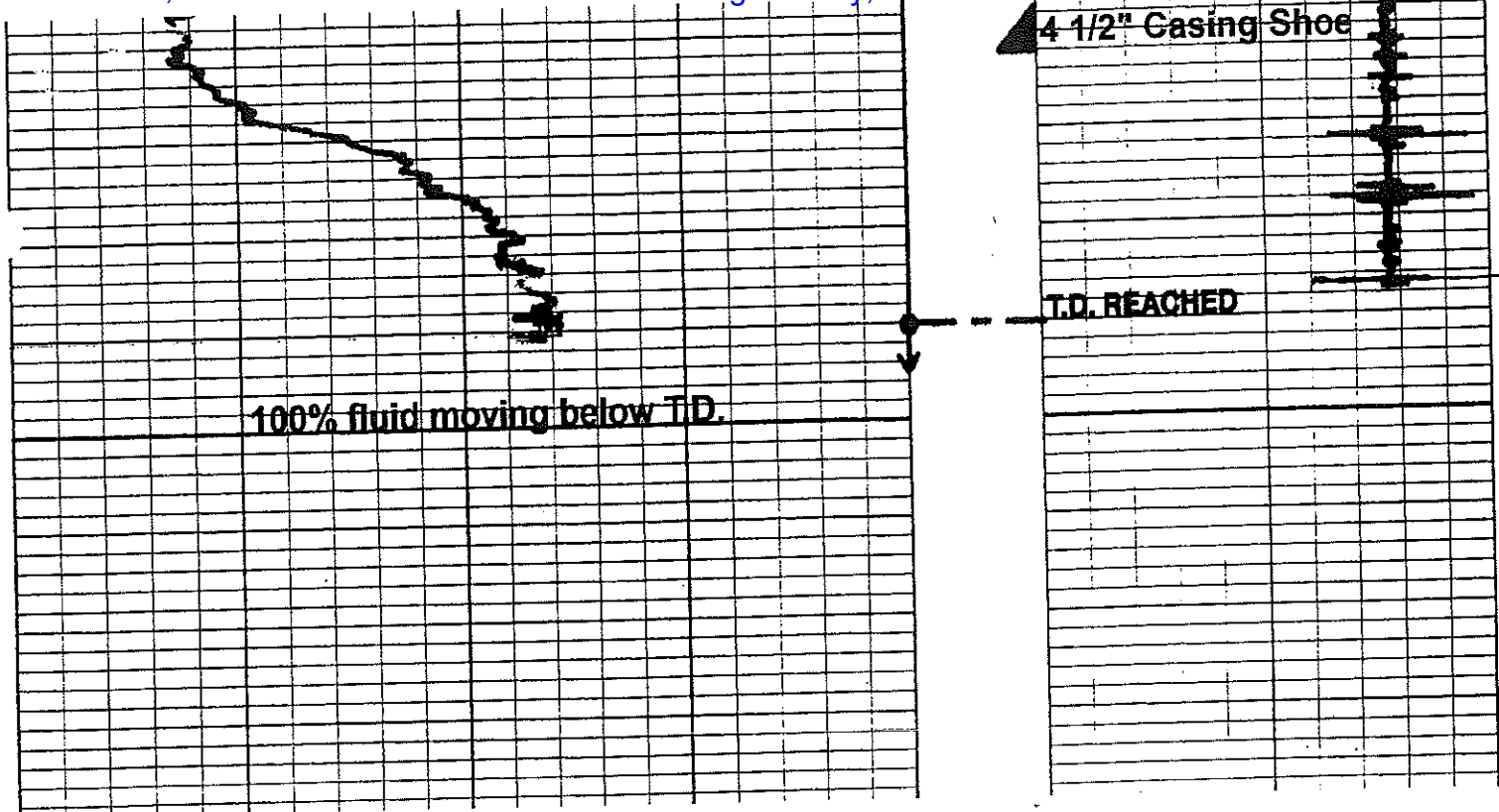
Exhibit "B-2"

B8

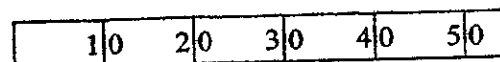


2550

2 3/8" Tubing



PERCENT OF INPUT



PERCENT PER FOOT

_____ GAMMA LOG

----- R/A FOLLOW UP TRACER

—————> RADIO ACTIVITY INCREASES

⋮ PERFORATIONS FROM CUSTOMERS RECORDS

—| SLOTS

█ CHANNEL

WARREN AMERICAN OIL CO., LLC
CHAPMAN #B-8
N/A FIELD
OSAGE CO., OK.
9/12/2017

Sta. Num.	Rate Bbls. Day	Depth. Interval	Percent of Fluid Going Below Base of Interval	Percent of Fluid Lost in Interval	Press P.S.I.
	885	100% FLUID MOVING BELOW T.D.			0
	NOTE:	NO LEAKS OR CHANNELS INDICATED UNDER EXISTING INJECTION CONDITIONS.			

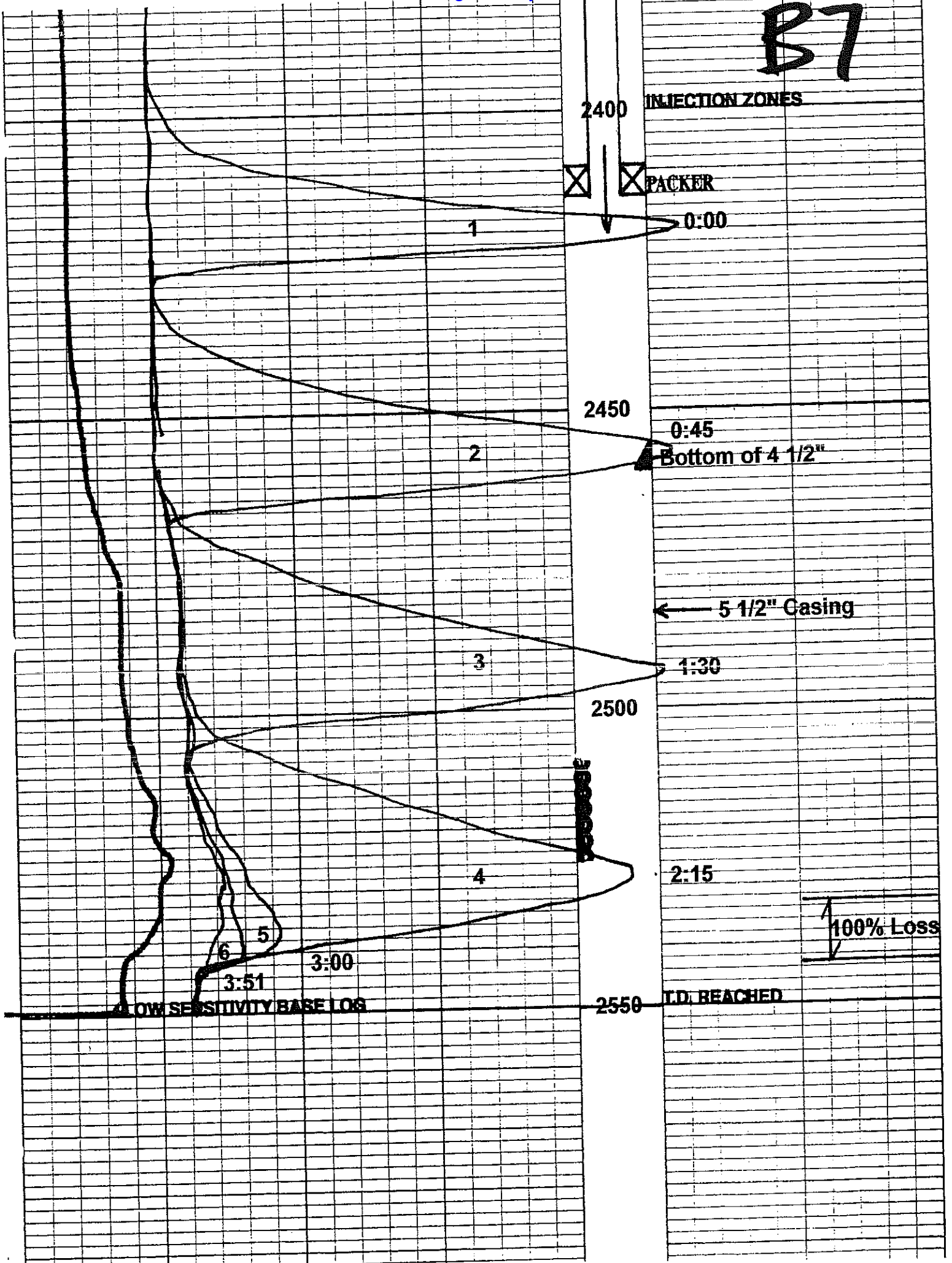
ASSOCIATED WIRELINE SERVICE, Inc.**580-229-0731 • Box 906 • Healdton, Oklahoma 73438**

Exhibit "B-3"

FILING NO.	COMPANY <u>WARREN AMERICAN OIL CO., LLC</u>					
	WELL <u>CHAPMAN #B-7</u>					
	FIELD <u>N/A</u>					
	COUNTY <u>OSAGE</u> STATE <u>OK.</u>					
LOCATION <u>API #35-113-34148</u>						TYPE SERVICES: INJECTION PROFILE
SEC <u>1</u> TWP <u>27N</u> RGE <u>7E</u>						
PERMANENT DATUM _____ ELEV. _____						ELEV. K.B. _____
LOG MEASURED FROM <u>8</u> FT ABOVE PERM DATUM						D.F. _____
DRILLING MEASURED FROM _____						G.L. _____
DATE	<u>10/2/2017</u>					INJECTION
RUN NO.	<u>ONE</u>					PRESSURE <u>120#</u>
TYPE LOG	<u>INJECTION PROFILE</u>					RATE <u>1138 BD.</u>
DEPTH-DRILLER	<u>2551</u>					FLUID <u>WATER</u>
DEPTH-LOGGED	<u>2550</u>					ISOTOPE <u>I-131</u>
BOTTOM LOGGED INTERVAL	<u>2550</u>					<u>8 DAY HALF LIFE</u>
TOP LOGGED INTERVAL	<u>2300</u>	CASING AND TUBING RECORD				
TYPE FLUID IN HOLE	<u>WATER</u>	SIZE	WGT	TYPE	FROM	TO
LEVEL	<u>FULL</u>					
RECORDING SPEED	<u>25'/MIN.</u>	<u>5 1/2"</u>	<u>14#</u>		<u>0</u>	<u>2551</u>
TOOL SIZE	<u>1"</u>	<u>2 3/8"</u>		<u>S.T.</u>	<u>0</u>	<u>2414</u>
RECORDED BY	<u>COX</u>	<u>4 1/2"</u>			<u>0</u>	<u>2460</u>
WITNESSED BY						
PERFORATIONS <u>2509-26</u>						
REMARKS: <u>SEE NOTE BELOW.</u>						

Exhibit "B-3"

B7





PERCENT PER FOOT

WARREN AMERICAN OIL CO., LLC

CHAPMAN #B-7

N/A FIELD

OSAGE CO., OK.

10/2/2017

CHANNEL

[illegible]

Comments submitted by
Kerry L. Sublette
Sarkeys Professor of Environmental Engineering
University of Tulsa
October 9, 2017



I have been asked to comment on certain assertions and findings referenced in the EPA Interim Final report titled "Bird Creek Investigation and Injection Well Response Action Plan" dated August 4, 2017. Each of these assertions or findings are given below followed by my comments.

Cation/anion analysis of injected fluids and high TDS waters show a match with the Mississippi Chat Formation (which is used for both oil production and an injection dispersal zone).

Stiff diagrams as visual representations of water composition are ambiguous when strongly dominated by one cation/anion pair such as Na^+ and Cl^- . Stiff diagrams can readily demonstrate that fresh water has been impacted with a produced water. It is much more difficult to demonstrate that fresh water has been impacted by a particular produced water. Definitive identification of a particular produced water requires analysis of minor components (As, Se, Cr, radioisotopes, etc) and/or isotopic analysis of $\delta^{18}\text{O}$, $\delta^2\text{H}$, and $^{87/86}\text{Sr}$. Isotopic analysis is the current state of the art for forensic analysis of produced water impacts. Thus with the available data it can be concluded that the Bird Creek tributary was impacted by produced water but the source of that water remains unknown.

Surface water concentrations at the originally reported location (Monitoring Station 2, MS2) have declined steadily and significantly since the Jireh Resources Well 18 (OS6320) was repaired in September 2016 following an MIT failure.

Further declines at the original location (MS2) also occurred immediately after the shut-in of the Novy/Greyhorse disposal well (S5258) due to MIT failure.

High TDS remains at MS6, ½ mile downstream of the original location.

In the absence of significant turbulence introduction of saline waters into fresh water streams or rivers produces a stratified condition with the denser saline waters near the bottom and the fresh water above. If the depth of the stream is uniform the saline waters and the fresh water will flow more or less together in a stratified flow. If the stratified flow encounters a deep pool the denser saline waters will be accumulated in the pools. Under ordinary flow conditions transport of salts out of the deeper layers of these pools occurs through diffusion and convective currents that operate near the boundary of the saline waters and fresh water in what can be considered a mixing or transition zone. Under normal flow conditions these mechanisms will only slowly

WARREN
AMERICAN

4

transport salts downstream. Therefore, it has been observed that these stratified pools are often persistent over a long period of time. It is also well established that significant transport of salts out of a stratified pool requires turbulent mixing of the pools to scour saline waters out of the pool to mix with fresh water to be transported downstream. This type of turbulence results from significant rain events. The efficiency of any rain event to scour salts from the pools depends on the rain intensity, the depth of the pool and the geometry of the pool especially the slope of the downgradient wall of the pool. Following such an event it is not uncommon for salts transported downstream to collect in another pool and reform stratified layers of water based on density. Therefore, following large rain events significant fractions of the salts can be transported pool to pool. Cumulative rainfall is far less significant in determining salt transport from these pools.

Another consequence of the formation and persistence of these stratified pools is the formation of a temperature gradient where higher temperatures are measured in the dense saline layer at the bottom of the pool. Solar infrared radiation is absorbed by the bottom of the pool which heats the saline layer. The fresh water above acts as an insulator slowing the dissipation of the heat vertically. There are many examples of natural lakes of various depths, for example, with saline inputs that have resulted in stratified layers based on salt concentration and density where the dense saline layers are heated by the sun relative to the fresh water above.

Two pools in the tributary to Bird Creek were referenced extensively in the cited referenced interim final report, the pool at MS2 and the much deeper pool at MS6. The salinity and temperature data collected to date are consistent with a single release of produced water at or near MS2 in August 2016. All observations of increased or persistent salinity and elevated deep pool temperatures downstream of MS2 can be explained by stratified flow and pool to pool transport of salts as described above. Specifically the steady decline in bottom TDS in MS2 is consistent with the repeated scouring during significant rain events such as those shown below based on Foraker mesonet daily rainfall totals. Only rain events exceeding 1 inch are shown.

Date	Rainfall (in)
September 9, 2016	1.75
January 15, 2017	1.89
March 29, 2017	1.35
April 16, 2017	2.37
April 17, 2017	1.83
April 21, 2017	1.27
April 25, 2017	1.00
April 29, 2017	3.78
May 3, 2017	1.88
May 11, 2017	1.53
August 5, 2017	3.89
August 6, 2017	1.64
September 26, 2017	1.51

Given the expected behavior of stratified saline/fresh water pools during these types of rain events and the turbulence they would have created it is no surprise that the TDS in the pool at MS2 has decreased over this time period. Further the TDS in the pool at MS6 would be expected to increase and then decrease over the same time interval as has been observed. In the intervening periods between large rain events when rainfalls were low any salt-laden pools like that at MS6 would stratify and solar heating of the dense saline layer would be evident. In summary, with a reasonable degree of scientific certainty this is expected behavior consistent with a single discharge event in August 2016 at or near MS2. The TDS data alone cannot prove a cause-effect relationship between the TDS in the tributary and either the repair of the Jireh well in September 2016 or the shut in of the Novy/Greyhorse well on May 9, 2017 (note the large rain event two days later).

Monitoring at some locations indicates that despite repairs to the Jireh Well 18W (OS6320) and shut-in (termination) of the Novy/Grayhorse well, injection operations appeared to affect in-stream water quality (TDS) before and after the coordinated shut-in event, but amplitude (degree of variability) of short term concentration fluctuations at some stations diminished during the shut-in period. This indicates ongoing impacts from the injection operations unrelated to the mechanical integrity failures of these two wells.

First of all, the expected pool-to-pool transport of salt in the stratified tributary and the depth of the pool at MS6 fully accounts for the appearance of salt contamination in the pool at MS6 and its long-term persistence as a dense, high-TDS layer in this deep pool. The much greater depth of this pool explains why this pool has not been as completely scoured as the more shallow pool at MS2.

The reference to variability in TDS seems to primarily refer to the difference in variability in TDS measurements at depth in the pool at MS6 prior to and after July 1, 2017. From the plot of TDS vs. time in the EPA report titled "In-Stream Monitoring Project at the Tributary of North Bird Creek Area" it appears that the increase in the amplitude of these variations followed removal of the sensor from the water (note TDS goes to zero) for cleaning, maintenance, or calibration. It is only after replacing the probe does the amplitude of these variations show a significant increase. The field technician could not be sure the sensor was replaced in the same spot. Most importantly the field technician could not be sure that the sensor was replaced at the same depth given the likely slope of the bottom of the pool. If the sensor was placed at a location higher in the dense saline layer closer to the transition zone between the dense saline layer and the fresh water above then the variability in the TDS could possibly be explained by the daily solar heating pattern. The TDS in the transition zone would be expected to be more sensitive to convective currents produced by heating during the day. In other words small variations in TDS were produced daily due to heat-induced differences in density and the resulting small-scale circulation of the water. At night, without solar heating some of these convective currents would be expected to relax.

In summary, the change in the amplitude of the TDS variations occurring immediately after the sensor was removed and replaced makes the cause of the change highly suspect. It is plausible that replacement of the sensor at a different vertical depth resulted in the change.

Recommendations

A major question that the above cited interim final report seeks to address is whether there is ongoing salt input to the Bird Creek tributary. The persistence of a high TDS saline layer in the pool at MS6 seems to be of most concern with regard to this question. As outlined above it is my opinion that all observations to date are consistent with a one-time event resulting in a large influx of produced water (and oil) into the tributary at or near MS2 in August 2016. However, there is a simple experiment that can be conducted to provide further evidence to support either position. The dense saline layer in the pool at MS6 could be pumped out for disposal allowing fresh water to return to the deeper regions of the pool. The TDS of the pool could then be monitored over time. If the TDS increases again then there is an ongoing input to the pool. In my opinion, the pumping and disposal process should be carried out in 2-3 stages. The removal process will result in some vertical mixing with some salt escaping removal in the first effort requiring a 2nd or 3rd trial (after re-stratifying) to fully remove the salt. Also given the age of the dense saline layer it is expected that salts will have diffused into the sediments. The time period between repeated withdrawals will allow the sediments to re-equilibrate with the water.